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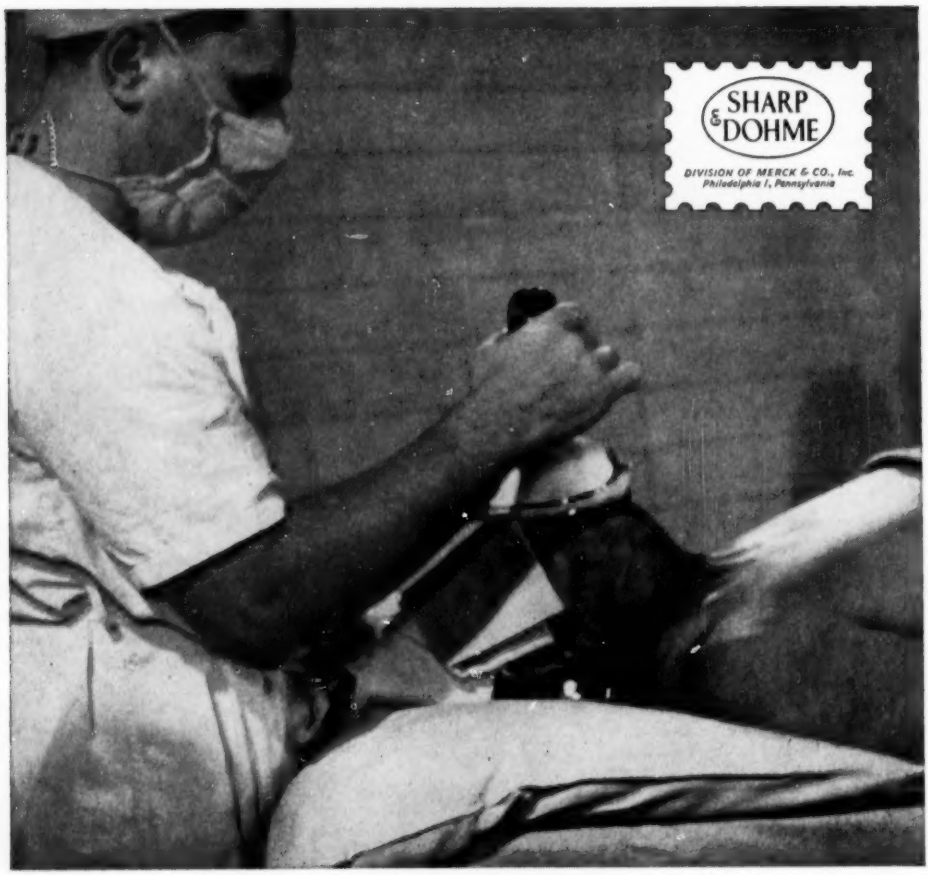

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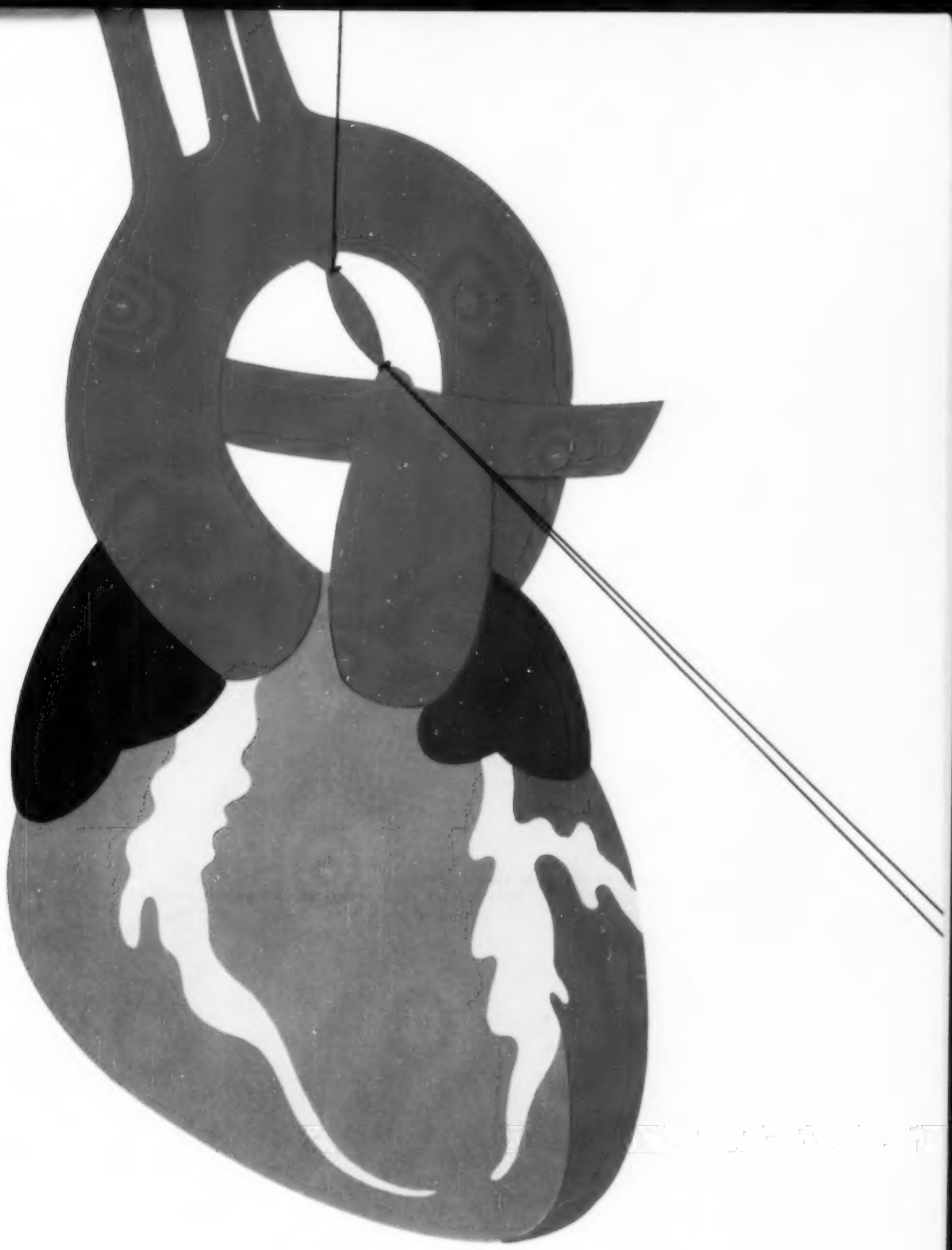

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4. Wolman, B., et al.: Brit. M. J. *1*:419 (Feb. 23) 1952.
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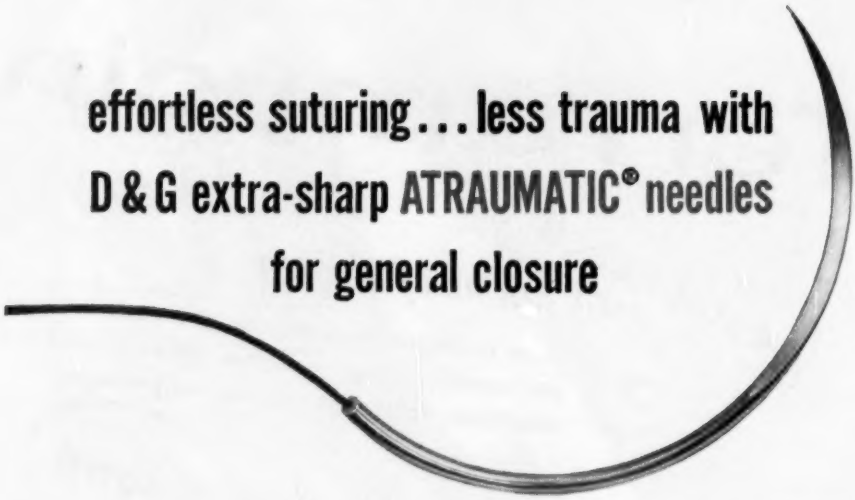

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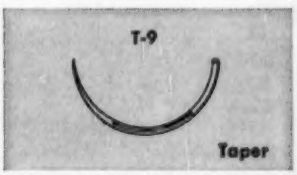

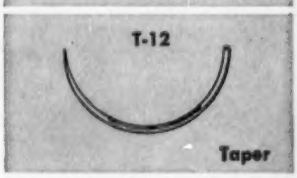

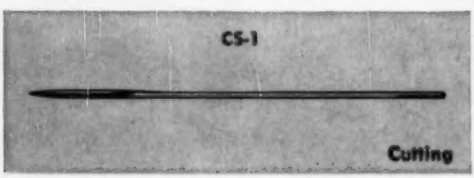

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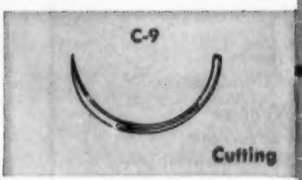

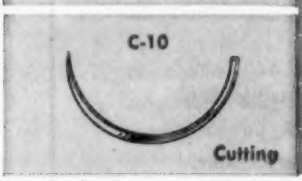

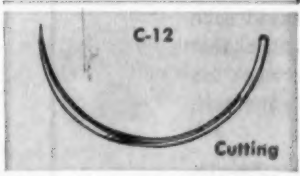

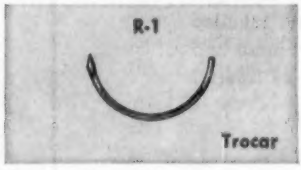

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Editorials

THE DOG IN MEDICAL RESEARCH

THIS EDITORIAL is written for the purpose of directing attention to a publication by the United States Department of Health, Education, and Welfare on the care of the dog in research institutions. This pamphlet fills a need in medical research, and it is suggested that every institution using dogs for medical research conform to the principles of dog care as presented in this pamphlet. It can be procured from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

There are several reasons for the adoption of these principles of dog care by every research institution. One of the most compelling reasons concerns science itself. The results can be thrown off if an experimental study is carried out on sick dogs. Additional variables are introduced into a scientific study if dogs are used that are not in normal health. Such variables, if they become a part of a published report, can do positive harm to science. Only healthy dogs should be used for critical experimentation.

Another compelling reason for the use of only healthy dogs concerns the expenditure of time and money for animal experimentation. The use of dogs that are not in normal health involves a great waste. This waste has been so great in the past that surgeons doing experimental work have closed down their laboratories during the seasons of the year when distemper is prevalent. It is an almost complete waste of time to do experiments on dogs that have distemper. Dogs are susceptible to infectious diseases. These diseases under conditions laid down in the pamphlet can be completely or almost completely stamped out. This pamphlet also contains a discussion on nutrition of the dog. The nutritional condition of the dog can also be a factor in the experimental study and can throw off its results.

Another reason for proper care of dogs concerns the relationship of society toward animal experimentation. The institutional care of the dog should be as good as or better than the care given by society in general. The quarters for dogs should be clean and light and not overcrowded. The quarters should be such at all times that a reasonable visitor could be taken through them without adverse comment.

This pamphlet contains standards of care that were considered to be minimal and satisfactory. It was prepared by individuals who were familiar with the problems of dog care and included several veterinarians, together with a group of surgeons and pathologists. The cost of proper care is not insignificant. No institution should try to do it on a "shoestring." Such experimentation should be done only in those institutions in which there is an adequate budget for proper care of the animals.

CLAUDE S. BECK, M.D.

TOURNIQUET PARALYSIS SYNDROME

JOSEPH MOLDAVER, M.D.
NEW YORK

A TOURNIQUET is usually applied as a first-aid measure to stop bleeding when blood vessels are damaged in battle casualties as well as with injuries in civilian life. It is also widely used in orthopedic, nerve, or plastic surgery when a bloodless field is required.

Paralysis induced by a tourniquet is said to be rare, and very few cases have been reported in the literature. The statistics would probably be increased if one were more aware of the existence of the characteristic clinical syndrome which may follow the application of a tourniquet and which is the subject of this paper.

This complication can be overlooked for several reasons. First, the paralysis and the associated phenomena can be of relatively short duration. Secondly, the lesion can be a mild one and result in an incomplete paralysis, which may be interpreted as difficulty in moving the parts because of the surgery. And, thirdly, the sensory examination is usually confined to the testing of pain sensation with a pin prick and, because of the supposedly normal sensory findings, the incomplete or even complete paralysis is often erroneously diagnosed as hysterical.

In spite of extensive experimental work in the animal and numerous studies in man, the mechanism of the paralysis itself has not been established. Most of the workers have attributed the symptoms to ischemia of the nerve. Sometimes the complication induced by a tourniquet has been erroneously associated with the Volkman type of contracture, which is a completely different syndrome.

The tourniquet is obviously an instrument which can produce ischemia, but depending upon the type used, the duration of its application, and the amount of pressure it can also cut deeply into skin, muscles, and nerves.

The symptoms observed in tourniquet paralysis can be identical with those seen in some cases of pressure paralysis. The first good clinical studies on the effect of compression on nerves in man were reported by J. B. Bastien and A. Vulpian in 1855. In 1861 Duchenne de Boulogne described several cases of pressure paralysis in which the palsied muscles retained normal excitability to electrical stimulation. In 1862 A. Waller described the different symptoms of pressure on nerves in man. In 1872 S. W. Mitchell showed various forms of pressure resulting in paralysis. In 1876 W. H. Erb studied the electrical stimulation of the nerves, and he also reported cases with normal response to stimulation of the distal end of the nerve. In 1899 J. J. Déjérine and Bernheim reported one case with autopsy in which there was an injury to the radial nerve with conduction loss and in which the excitability was

From the Department of Neurology, Columbia University College of Physicians and Surgeons; the Neurological Institute of the Presbyterian Hospital, and the Hospital for Special Surgery.

retained below the injury. In 1920 C. H. Frazier and S. Silbert described injuries in which the nerves were not affected directly but in which a bullet had caused an indirect injury to the nerve, resulting in a dissociation of motor and sensory findings. In 1923 G. Bourguignon and H. Laugier studied the disturbance in sensations and loss of conduction of motor nerves due to temporary ischemia, using both inflated cuff and an Esmarch bandage. In 1931 T. Lewis and E. E. Pochin made extensive studies on paralysis and dissociation of sensations resulting from either the experimental use of an inflated cuff or from direct pressure on nerves. Cases with tourniquet paralysis were reported by N. L. Eckhoff in 1931. A series of interesting experiments on paralysis induced in animals by direct pressure or by tourniquet were performed by D. Denny-Brown and C. Brenner in 1944; they also described one case in man. In 1945 J. Speigel and P. Lewin reported three cases in which the nerve was damaged by the use of rubber tourniquets.

A great number of studies have been made on conduction and blood supply of nerves, which are interesting but are too numerous to be analyzed here.

The reversible disturbances in sensations and the paralysis resulting from the experimental use of an inflated cuff have been analyzed by different authors. The data is conflicting because the loss of sensations is often so rapid and the various defects are so much intermingled that it is difficult to make a thorough study of each individual mode of sensation; furthermore, the experiments are usually accompanied by some discomfort and even pain, which increase the difficulty of the study. After release of pressure the return of the different functions occurs so rapidly and the accompanying paresthesiae and tinglings are so strong that it makes the study of the sensations difficult to analyze.

CASE MATERIAL

In cases of tourniquet paralysis an analysis of the different sensations is relatively easier, because there is usually a very slow return of the different functions. The electrical and sensory tests can be repeated many times on one patient, and the findings can be checked from day to day. In some of those cases the patients have been followed for many weeks until complete recovery.

It is also interesting to point out that in none of the patients examined was there any spontaneous pain or any paresthesia that would interfere with the study of the defects in sensations.

Seven cases of complete paralysis resulting from the use of a tourniquet have been studied. Three were induced by rubber tube, two were the result of Esmarch bandages, and two were due to the use of an inflated cuff.

In addition to those seven cases of tourniquet paralysis, over 100 cases of pressure paralysis of different nerves have been examined. These cases may have quite similar symptoms and will be the subject of a later report.

Two cases of tourniquet paralysis syndrome will be described in detail. The findings in the other five cases were exactly similar.

CASE 1.—A 40-year-old woman was admitted to the hospital for the removal of a ganglion of the right wrist and was operated on March 15, 1951. A towel was applied on the upper arm and over it an Esmarch bandage was tied around the arm several times. The operation lasted 47 minutes.

After the operation the patient complained of complete paralysis of the muscles of the forearm and hand and numbness of the hand. She was examined by me for the first time 14 days after the onset and about once a week at regular intervals for over three months until complete

recovery. The patient was of dark complexion. At 8 cm. above the elbow there was a small and well-defined band of very dark pigmentation of the skin, 2 mm. in width, encircling the upper arm. Apparently more pressure was applied at that level, resulting in an actual damage to the skin.

On first examination, 14 days after the onset of paralysis, the following signs were noticed (Fig. 1):

Motor function: There was complete paralysis of all muscles of the forearm and hand supplied by the median and ulnar nerves and also of all muscles supplied by the radial nerve below the brachioradialis muscle; the anconeus muscle escaped paralysis.

Light touch: When tested with cotton or von Frey's hairs, there was absence of sensation in the entire palm of the hand, in the dorsum of the tip of the fingers, and in an area between the thumb and index finger in the dorsum; the loss of touch sensation corresponded consequently to the distribution of the radial, median, and ulnar nerves.

Superficial pressure: This was also lost in the same area as touch; the patient was unable to feel the heaviest von Frey's hair.

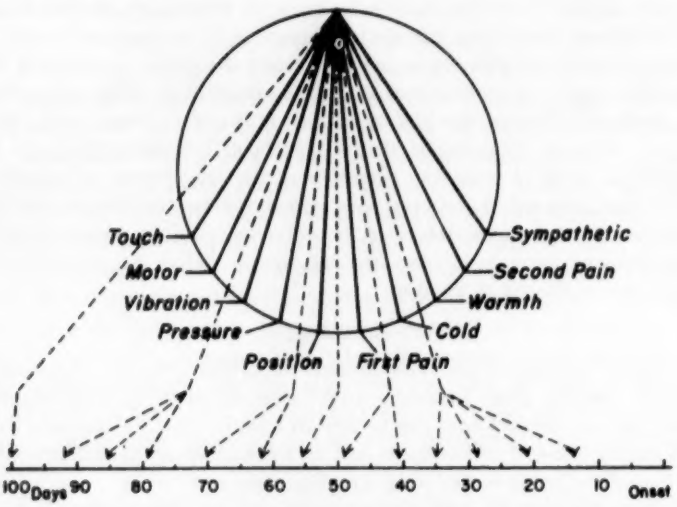

Fig. 1.—Tests were done at regular intervals after onset, as indicated by arrows. Dotted line to extreme right separates unaffected from affected modalities. Remaining dotted lines indicate time of return of affected modalities. There was a progressive return to normal, motor and touch being the last functions to recover. Syndrome in this case was typical 56 days after onset. Before this time it was slightly unusual because of severity of injury to nerve, with involvement of cold and first pain. During entire period of paralysis, stimulation of distal end of nerves resulted in normal muscular responses. There was a block of conduction where the tourniquet was applied, that is, no response to stimulation above lesion.

Proprioceptive sensation: Position sense and appreciation of passive movements was absent in all fingers and in the wrist.

Vibration sensation: This was absent in the hand and wrist.

Superficial pain: The entire palm of the hand was very painful to pin prick. In the area supplied by the median nerve there was a delay of 1 to 1.2 seconds in perception of pain for the distal phalanges of the thumb, index, and middle fingers. The threshold for pain, measured with the algesiometer, was of an average of 20 gm. in the distribution of the median nerve and 10 gm. in ulnar distribution. The sensation of pain was accompanied by a strong affective reaction and was particularly unpleasant. On the normal hand, 20 gm. for the median nerve distribution was felt as a sharp point but it was not actually painful.

Temperature sensation: The appreciation of cold was slightly disturbed in the hand; the answers were irregular. Warmth sensation was normal.

Skin resistance: Comparison with the normal hand showed no difference except for a small patch of increased resistance of about 1 cm. square in the thenar region.

Electrical testing: Stimulation of the median and ulnar nerves either at the elbow or at the wrist resulted in normal responses in all muscles innervated by these nerves. Stimulation of the same nerves above the elbow just below the line of pigmentation resulted in a normal response. Stimulation of the radial nerve at that level also resulted in a good response. When the stimulating electrode was applied to either of those three nerves just above the pigmentation line, there was no response. There was complete block of conduction even with very strong current.

Direct stimulation of the motor points of the different muscles supplied by the median, ulnar, and radial nerves showed normal excitability. Chronaxie figures and strength-duration curves were normal with the exception of the thenar and hypothenar muscles and the first and fourth dorsal interossei muscles which showed some denervated muscle fibers. Denervation was characterized by a slow response to stimulation with a current of long duration, a shift of the strength-duration curve to the longer time. There was an increase of the chronaxie figures up to 10 times the normal value. The stimulation of the ulnar and the median nerves at the elbow and at the wrist with a constant current failed to give the usual tingling sensation referred to the palm of the hand that they supply. The sensation of tingling was also absent when the stimulation was applied to the nerve below the small band of skin pigmentation but was felt when the stimulating electrode was applied just above that area; the tingling was referred to the hand. It is interesting to note that this patient at no time had experienced any paresthesia or any spontaneous pins-and-needles sensations.

Pilomotor reflex was strong in the entire forearm when electrical stimulation was used. Plethysmographic recordings of the fifth finger were also taken, and they showed the same readings as on the left side. The hand was warm, pulse was good, and oscillometric readings in the forearm were normal. One week later, that is, 21 days after onset, there was no significant change in the clinical findings.

Testing 28 days after onset of paralysis gave the following results:

Motor function: There was still complete paralysis of all muscles.

Proprioceptive sensation, vibration sense, light touch and pressure sensation were still completely absent.

Superficial pain was increased, as mentioned previously, but a pressure of 10 gm. when using the algesiometer was very painful in the distribution of the median and ulnar nerves. The threshold of pain was diminished. The same delay in the perception of pain was noticed, that is, 1 or 1.2 seconds.

Heat and cold sensations were normal.

Skin resistance was normal.

Electrical testing showed the same findings; conduction block for the median, ulnar, and radial nerves.

Testing 41 days after onset gave the following results:

Motor function: For the first time there was a trace of contraction in the first dorsal interosseous muscle, but there was still complete paralysis in all the other muscles.

Light touch with cotton or with the von Frey's hairs showed complete anesthesia for the median, ulnar, and radial nerves.

Superficial pressure, proprioceptive, and vibration sensations were still absent.

Superficial pain: There was a delay of 1 to 1.2 seconds when the tip of the thumb, index and middle fingers were tested for pain either with the pin prick or with the lowest pressure of the algesiometer, that is, 2 gm. Pain sensation was still increased and was accompanied by a strong affective reaction.

Heat and cold sensations were normal. Skin resistance was normal.

Electrical stimulation showed no change. There was a normal response below the lesion and no response above the pigmentation line, with the exception of a slight response in the first dorsal interosseous muscle.

Testing 49 days after onset gave the following results:

Motor function: With voluntary motion there was a slight contraction in the first and second dorsal interossei and a trace of contraction in the flexor carpi ulnaris and also in the palmaris longus. Other muscles were still completely paralyzed.

Touch sensation: There was complete anesthesia when tested with cotton-wool and von Frey's hair. Vibratory sense showed some return in the hand but was absent in the index and middle fingers.

Proprioceptive sensation and appreciation of passive motion were disturbed in the fifth and middle fingers but were normal in the other fingers as well as in the wrist.

Superficial pressure was painful in the thenar muscles but not elsewhere.

Superficial pain: Pin prick sensation as well as 2 gm. with the algesiometer was very painful. There was no delay in the perception.

Electrical stimulation of the nerves above the tourniquet line resulted in response in the muscles that the patient could contract with voluntary motions.

Subsequent examinations showed a slow return of the different modes of sensations and of motor functions. When the patient was able to contract certain muscles with voluntary effort, they could always be stimulated when the active electrode was applied above the line of pigmentation. Below the line the response was always good.

Testing 100 days after the onset gave the following results:

Motor functions: The return of motor function was complete in all muscles.

Proprioceptive, vibration and superficial pressure sensations were normal.

Temperature sensation and skin resistance were normal.

Light touch was normal in the entire hand except for hypesthesia in the distal phalanx of the middle finger.

Superficial pain: Pin prick was felt as very painful and definitely sharper in the entire thumb and in the index finger as compared with the normal parts of that hand or as compared with the other hand.

The electrical stimulation showed normal responses below as well as above the pigmentation line marked by the tourniquet.

Case 2.—A 21-year-old man had suffered from severe generalized rheumatoid arthritis since the age of 7. It was rather difficult to evaluate the muscular functions of the left arm because of the ankylosis of the elbow, wrist, and of the metacarpal joints of some of the fingers. He had good use of the index finger and thumb and had fairly good range of motion in the distal phalangeal joints. The different modes of sensations were normal. He was operated on for the ankylosis of the left elbow. An arthroplasty with excision of the radial head was performed. This was done on Nov. 7, 1949. A rubber-tube type tourniquet was applied for an hour and a half without incident.

On March 28, 1951, he was operated on again for revision of the elbow arthroplasty. The regular inflated cuff tourniquet was not available at that time, and since the patient had no difficulty with the rubber tube tourniquet in his previous operation this was used again. It was applied for 2 hours 40 minutes.

Soon after the operation all motion of the fingers was lost.

Thirty-eight days after the onset, there was complete paralysis of all muscles supplied by the radial, median, and ulnar nerves.

Electrical stimulation of those nerves proximal to the site of the application of the tourniquet failed to give any response in the muscles supplied by them. At the elbow and at the wrist there was a good response to stimulation of the nerves. A few denervated muscle fibers were found in the abductor digiti quinti and in the abductor pollicis brevis, but all the other muscles had normal excitability to direct stimulation.

Proprioceptive sensation: Position sense and appreciation of passive motion in all of the joints that were not previously ankylosed, that is, the thumb and index and distal phalanges of all fingers were completely lost (Fig. 2).

Vibratory sense was absent in the entire hand.

Light touch: There was absence of sensation to cotton and the von Frey's hair in the ulnar and median nerves. There was normal touch sensation in the radial nerve distribution.

Light pressure was not felt; deep pressure on the tip of the thumb, index, and middle fingers was painful, but not on the fourth and fifth fingers.

Warmth and cold sensations were not affected.

Skin resistance was normal.

Superficial pain: Pin prick was very painful, and there was strong affective reaction, with withdrawal of the extremity. With the smallest pressure of the algesiometer, that is, 2 gm., the sensation was painful and unpleasant as compared with the normal skin. This was a real hyperalgesia, with diminished threshold of pain. There was no delay in the sensation of pain, indicating that the fast pain fibers were not affected. Stimulation of the skin of the tip of the fingers with electrical current of small intensity resulted also in a very unpleasant sensation of pain without any delay. When a constant electrical current was used on the median and ulnar nerves at the wrist, the normal tingling sensation referred to the hand was absent. There was only a shock-like sensation going down to the fingers.

Testing 74 and 88 days after onset gave the following results:

Motor function: There was partial return of motion in the extensor pollicis longus, abductor pollicis longus, and in the thenar muscles and flexor profundus for the third, fourth, and fifth fingers.

Proprioception: Positional sense was normal. Appreciation of passive motion was normal.

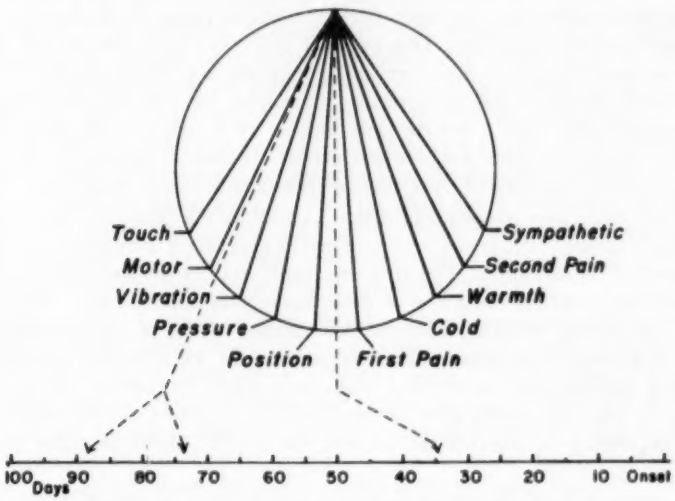

Fig. 2.—Tourniquet paralysis syndrome with typical sensory dissociation. First examination was done 35 days after onset of paralysis. There was a block of conduction at site of application of tourniquet. Muscular response to electrical stimulation of nerve distal to injury was always normal. Dotted line separates unaffected functions on right side of circle from affected ones on left. When tested 74 and 88 days after onset, position, pressure, and vibration sensations had recovered; motor and touch were still affected and they were the last functions to recover.

Vibratory sense was normal.

There was slight pain to deep pressure in the tip of the third, fourth, and fifth fingers.

Light touch: There was absence of touch sensation when tested with cotton in the entire palm of the hand. Both median and ulnar nerves were still affected. Tests with the von Frey's hair showed impairment of touch.

Light pressure was felt normally.

Sensations of warmth and cold were normal. Skin resistance was normal.

Superficial pain: Pin prick was still very painful using the smallest pressure of the algesiometer, that is, 2 gm. There was also a strong affective reaction.

Electrical stimulation of the ulnar and median nerves at the wrist resulted in a shock-like sensation, but there was no tingling.

Ninety-five days after onset, there was complete return of motor function; sensation was normal. There was no unusual pain to pin prick. There was a normal tingling to electrical stimulation of the median and ulnar nerves at the wrist. There was no block of conduction.

It is worth noticing that after the first operation, when a rubber-tube tourniquet was applied for an hour and a half and when there was no complication, a very strong tingling sensation followed the release of the tourniquet. After the second operation there was no tingling sensation or any paresthesia, indicating a block of the fibers responsible for the tingling.

In the other five patients with tourniquet paralysis there were similar findings.

COMMENT

The purpose of this paper is not to attempt to explain the type of tourniquet that should be used nor its mode of application but rather to give a description of the clinical symptoms that accompany a tourniquet paralysis. The study of one or more cases can be found in the literature, but none of the authors has described the existence of an actual syndrome.

It is well known that the number of cases of tourniquet paralysis has decreased since the thick rubber tube has been avoided and the Esmarch bandage or, rather, the inflated cuff has been used. This by itself indicates that ischemia most likely is not the cause of the complications resulting from the application of the tourniquet, since ischemia should be the same for any tourniquet, but that the mechanical pressure plays a greater role, if not the only one, in the etiology of the paralysis. The tourniquet should be applied where the nerves are best protected by the muscles and, if possible, should avoid compressing them against bony structures.

The two cases here reported in detail, as well as the other five cases, indicate clearly that damage to the nerves was confined to the narrow area where the pressure was applied at its maximum. The area was small and sharply localized. In the first case there was a well-defined line of dark pigmentation of the skin. There was a block of conduction which affected the three mixed nerves of the forearm—radial, median, and ulnar. This was easily demonstrated by the electrical stimulation. A very slight displacement, or about 2 mm., or a slight rotation of the stimulating electrode on the skin would give or fail to give a response in the corresponding muscles depending on whether the current was applied above or below the nerve block.

The nerves distal to the block had normal responses to electrical stimulations. This obviously indicates that the ischemia that took place below the line of pressure did not result in any change in the excitability of the nerves and the muscles. In addition, the electrical stimulation of the mixed nerves with a constant current distal to the line failed to elicit the usual tingling sensation referred to the hand. When the stimulating electrode was slightly rotated and displaced above the line of damage, a strong tingling sensation referred to the area of the skin supplied by the sensory fibers of the nerves took place. This obviously indicates that the touch fibers were intact central to the site of the injury. Furthermore, it also indicates that the sensory fibers, in the first case, for instance, were not affected above the line of pigmentation, and yet the Esmarch's bandage had been applied over a wide area of the upper arm. There is consequently no doubt that there was a damage to the nerve exactly at the level where the line of pigmentation was noticeable. Yet the ischemia due to the application of the tourniquet took place in a much larger area. Therefore, the block of conduction of the motor fibers as well as the sensory dissociation were the result of the mechanical pressure localized to a very narrow area and were not the result of the ischemia, which involved a large part of the upper arm and the entire forearm and hand. In the first case, the anconeus muscle was the only muscle of the forearm

that escaped paralysis. The nerve branch that supplied that muscle escaped injury most likely because it was deeply located and protected by the triceps muscle against direct pressure.

Paresthesiae or pins-and-needles sensations are typical and characteristic symptoms in all experiments in which the inflated cuff has been applied above systolic pressure for a certain length of time. It is interesting to notice that none of the patients with tourniquet paralysis, nor any of the patients with pressure paralysis, experienced any paresthesia at any time. There was no spontaneous tingling sensation.

Obviously, in patients with either tourniquet paralysis or pressure paralysis, the tingling sensation is absent because of the block of the fibers conducting that sensation, namely touch fibers. Consequently, the absence of paresthesia becomes an important diagnostic and prognostic symptom.

Occasionally, the sensation of warmth or cold may be slightly impaired, but this is rare. There may be some denervated muscle fibers in some of the paralyzed muscles. This would depend on whether or not, in addition to the block of conduction, there has been a more serious damage to some of the nerve fibers.

Pain sensation was always present. The first case was a rather a severe one. There was a delay in the pain perception because the first or fast pain fibers were affected, but they recovered after a relatively short time. The delay for the pain sensation of the finger tip was 1 to 1.2 seconds, which would indicate that the pain fibers that were able to conduct pain had a conduction time of about 1 meter per second. They were consequently the slow conducting fibers.

All patients with tourniquet paralysis who have been tested showed evidence of real hyperalgesia. There was an increased pain sensation with a low threshold. In addition, there was a very strong affective reaction. It is interesting to notice that in some areas of the hand, when the patient was recovering, the real hyperalgesia with low threshold was still present when touch sensation had returned to normal. Consequently, the hyperalgesia does not seem to be the result, as has been sometimes postulated, of the absence of touch or other sensations.

In tourniquet paralysis the syndrome consisted of a loss of the following functions: touch, motor, light pressure, vibration, and position senses. Warmth, cold sensation, pain, and sympathetic fibers were not affected. The affected functions would correspond most likely to the larger fibers described by Erlanger and Gasser, the A fibers. The larger fibers would consequently collapse before the smaller ones. If the damage is severer, as in the first case, the fast or first pain fibers and some of the fibers conveying cold sensation can to some extent be impaired. As a rule they are not involved in the tourniquet syndrome.

In none of the cases was there evidence of appreciable atrophy, because the motor fibers were still in continuity, as evidenced by the good response to the distal portion of the nerve and also because the repair took place in a relatively short time; very few muscle fibers were denervated. None of the patients showed evidence of a Tinel's sign. The return of function that takes place is apparently the result of a local repair. None of the cases showed any neuroma sign at the site of the injury.

When the syndrome of tourniquet paralysis is complete, the duration of the impairment of motor function and sensation can be as long as three months or even longer.

SUMMARY AND CONCLUSIONS

In a tourniquet paralysis there is a disturbance in the functions of the peripheral nerves which is apparently due to the mechanical pressure of the tourniquet on the nerve and is not the result of ischemia.

There is a constellation of symptoms that justify the term syndrome. The characteristics of this syndrome are as follows:

Motor function: There is paralysis with hypotonia or atonia, but no appreciable atrophy.

Sensory examination shows a dissociation of the sensations. The fibers subserving touch, pressure, vibration, and position sense are affected, and those sensations are usually absent. Pain sensation is never lost. In most of the cases there is actual hyperalgesia, that is, the pain is felt with a low threshold. In severe cases the first or fast pain can be affected. Heat and cold sensations are usually not affected or slightly disturbed.

There is no paresthesia or tinglings after release of the tourniquet, which is indicative of a block of the touch fibers, responsible for the tingling sensation. There is no Tinel's sign. There is no sign of neuroma at the site of the injury.

Sympathetic fibers are not affected. Pilomotor reflex is normal. Skin resistance is normal. Color of the limb is normal. Plethysmographic findings are normal. Temperature of the skin is normal.

Electrical studies show that there is a block of conduction characterized by lack of response to stimulation of the motor nerve above the injury, a good response below the injury. There is no tingling sensation to stimulation of the sensory fibers distal to the site of injury, but there is a tingling sensation when the nerve is stimulated proximal to the lesion. The electrical stimulation can localize the level of the lesion.

BIBLIOGRAPHY

Bentley, F. H., and Schlapp, W.: The Effects of Pressure on Conduction in Peripheral Nerves, J. Physiol. **102**:72-82, 1943.

Experiments on the Blood Supply of Nerves, J. Physiol. **102**:62-71, 1943.

Déjérine, J. J., and Bernheim: Sur un cas de paralysie radiale par compression, suivi d'autopsie, Rev. Neurol. **7**:725-788, 1899.

Denny-Brown, D., and Brenner, C.: Paralysis of Nerve Induced by Direct Pressure and by Tourniquet, Arch. Neurol. & Psychiat. **51**:1-26, 1944.

Duchenne de Boulogne, G. B. A.: De L'électrisation localisée, et son application à la pathologic et à la thérapeutique, Ed. 2, Paris, J.-B. Baillière & Fils, 1861.

Erb, W. H.: Diseases of Peripheral Cerebrospinal Nerves, in von Ziemssen, H. W., Editor; Cyclopedia of the Practice of Medicine, New York, Willian Wood & Company, 1876, Vol. 2.

Frazier, C. H., and Silbert, S.: Observations in 500 Cases of Injuries of the Peripheral Nerves at U. S. A. General Hospital No. II, Surg., Gynec. & Obst. **30**:50-65, 1920.

Erlanger, J., and Gasser, H. S.: Electrical Signs of Nervous Activity, Philadelphia, University of Pennsylvania Press, 1937.

Lewis, T., and Pochin, E. E.: Effects of Asphyxia and Pressure on the Sensory Nerves of Man, Clin. Sc. **3**:141-155, 1938.

Mitchell, S. W.: Injuries of the Nerves and Their Consequences, Philadelphia, J. B. Lippincott Company, 1872.

Moldaver, J.: Fibers and Tracts Conducting Tinglings of "Pins and Needles Sensation, Tr. Am. Neurol. A. **77**:189, 1952.

Waller, A.: On the Sensory Motor and Vasomotor Symptoms Resulting from Refrigeration and Compression of the Ulnar and Other Nerves in Man, Proc. Roy. Soc. London **12**:89-102, 1862-1863.

ACID-BASE BALANCE OF THE BLOOD IN DOGS AT REDUCED BODY TEMPERATURE

ROSS FLEMING, M.D., B.Sc. (Med.)
TORONTO, CANADA

HYPOTHERMIA and its application to surgery is a subject of much current interest both in the laboratory and in the operating room. Reduction of body temperature to low levels still has considerable risk, and ventricular fibrillation and cardiac standstill constitute the most serious complications. The present study was designed to determine what changes occur in the acid-base balance of the blood during cooling and to see whether alterations in the acid-base balance might influence the cardiac complications and mortality rate. If a pH change occurred during cooling, could it be controlled by the respiratory rate, by the concentration of gases inhaled, or by the administration of base or acid?

It is well known that when blood is cooled in vitro it becomes more alkaline.* There is, however, little information available about the acid-base changes of the blood in vivo when the body temperature is reduced. In hibernating animals there is always a marked increase in the carbon-dioxide content of the blood, with resulting gaseous acidosis.† Dubois [9] has suggested that this may be the cause of hibernation (autonarcosis). Concerning nonhibernating animals, available reports as to the effects of artificial hypothermia on the blood pH are very conflicting.‡

METHODS

1. *Induction and Maintenance of Hypothermia.*—These investigations have been carried out on dogs.§ After administration of thiopental (Pentothal) sodium-curare anesthetic, the animal was shaved and an endotracheal catheter inserted. The animal was then wrapped in special rubberized blankets through which alcohol at 0 C. was circulating. By this means the body temperature, as measured by a rectal thermocouple, was lowered to 20 C. during the course of about four hours. For rewarming, the animal was immersed in a water bath at 40 C., and his temperature returned to normal in one to two hours.

The respiratory rate of the anesthetized dog at 37 C. was about 30 to 35 breaths a minute. As the body temperature was lowered, respiratons became fewer, and spontaneous breathing usually ceased at about 23 to 25 C. (Fig. 1). As the body temperature approached 25 C., positive-pressure artificial respiration with pure oxygen was started at an average rate of five to six breaths a minute. This was continued until the termination of cooling and during rewarming until adequate spontaneous respirations returned at about 24 C. The oxygen was disconnected at about 32 C.

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From the Departments of Surgery and Pathological Chemistry, University of Toronto Faculty of Medicine.

* References 1 to 6.

† References 7 and 8.

‡ References 10, 11, and 12.

§ References 13 and 14.

The endotracheal tube was connected via a Y-tube to a cylinder of oxygen (Fig. 2). By closing off the open end of the Y manually or by means of an intermittent magnet, artificial respiration was given at any desired rate. In five of these dogs, carbogen (5% carbon dioxide in oxygen) was used instead of oxygen; as the acid-base changes were identical to those seen when pure oxygen was used, these animals were all considered together.

2. *Hydrogen-Ion Concentration.*—Blood pH was measured by means of a glass electrode enclosed in a 0.5 ml. anaerobic chamber (Beckman 290J; Fig. 3), with the use of a Beckman

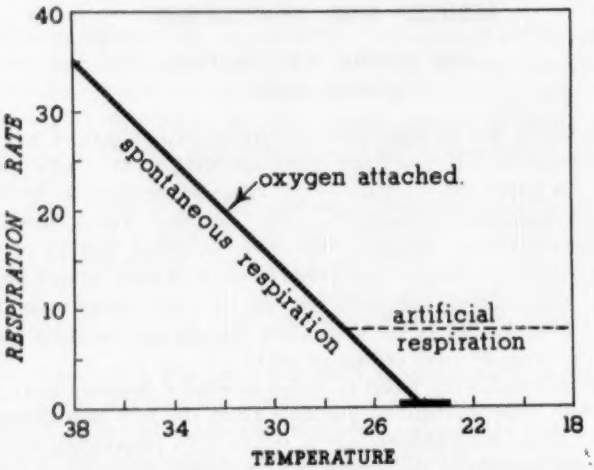


Fig. 1.—Showing decrease in respiratory rate as animal is cooled (solid line). Spontaneous respirations cease at about 25 to 23 C. These animals showed a marked fall in blood pH.

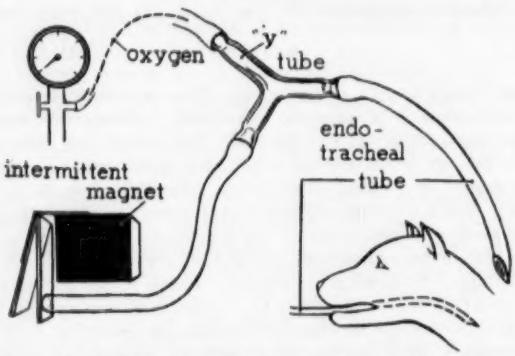


Fig. 2.—Showing method of giving artificial respiration with continuous flow of oxygen. By closing off the end of "Y" tube, either manually or by means of the intermittent magnet, gas is intermittently forced into animal's lungs at a predetermined rate and volume.

battery-operated pH meter. The blood samples were taken from the right atrium via a jugular catheter; 3 ml. of blood was withdrawn from the catheter and discarded; then an additional 3 ml. of blood was drawn into a heparinized syringe without the admission of air and without appreciable suction. This was immediately injected into the electrode cell in such a manner as to eliminate all the air from the cell, and then 1 ml. of blood was washed through the cell in order that the blood which first entered the cell, in contact with air, be quickly eliminated. pH readings were made between three and six minutes after withdrawal of the sample, after

all drift of the needle (caused by change in temperature of the blood sample) had ceased. This reading was then corrected to the temperature of the animal as outlined below. The meter was checked by reference to a standard phosphate buffer several times each day.

The major sources of possible error in the estimation of whole blood pH are as follows: (*a*) Exposure of the blood to air. This was minimized by the use of the anaerobic technique described above, thus avoiding gaseous interchange. (*b*) The addition of an anticoagulant. We have found that heparin has the smallest effect on pH, in spite of its high electrical activity. The solution of heparin that we use gives pH readings of 7.20 at 24 C., and one small drop added to 3 ml. of blood does not perceptibly alter the pH, yet prevents clotting. (*c*) Temperature, affecting ionic dissociation.

The pH of blood in vitro varies so greatly with the temperature that accurate pH values should be determined by maintaining the blood sample at body temperature. However, a temperature-controlled air environment for the electrodes, which can be rapidly varied to the animal temperature, would not be feasible. Moreover, shed blood at 38 C. becomes more acid within six minutes due to autoglycolysis,‖ but this change is delayed as long as two hours if

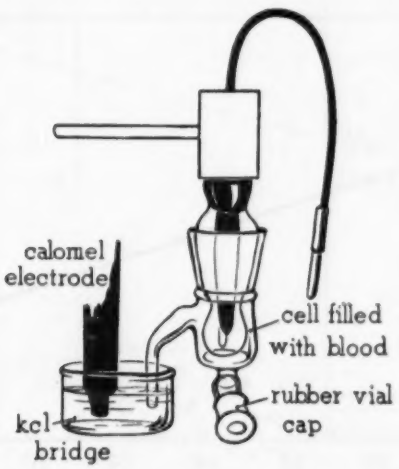


Fig. 3.—Anaerobic glass electrode for determining blood pH.

the blood be kept at 22 C. or room temperature. Therefore it was customary to withdraw the blood at body temperature, store it anaerobically, and allow it to assume room temperature before a pH reading was made. A temperature correction factor is then applied to the observed pH at room temperature to give the pH value at body temperature. Many investigators ¶ have reported, and we have confirmed, that the pH of dog whole blood in vitro decreases 0.0147 units per degree (C.) increase in temperature. This change in pH is completely reversible, thus proving that it is due only to changes in ionic dissociation and not due to gaseous interchange or chemical changes. We therefore applied to our whole blood pH values, the formula $pH_b = pH_r - (0.0147)(b - r)$ where b is body temperature, r is the room temperature at which the readings were made. All the pH values reported in this communication have been thus corrected.

3. *Carbon Dioxide Content of the Plasma.*—Blood for this determination was withdrawn from the venous catheter into an oiled and heparinized syringe, discharged into a centrifuge tube under a 2.5 cm. layer of oil, and spun down at 10,000 rpm for 15 minutes. Plasma CO_2 contents were determined in duplicate, the Van Slyke volumetric apparatus being used.

‖ References 3 and 4.
¶ References 3 to 8.

4. *Carbonic Acid Content.*—The pCO_2 was calculated by plotting the pH and CO_2 content on a nomogram published by Singer and Hastings.[15]

5. *Other Cations.*—Plasma chlorides were determined by titration with mercuric nitrate.[16] Lactic acid levels of the blood were estimated by the method of Barker and Summerson.[17] The Rothera test was performed on the plasma in order to detect the presence of ketone bodies. Inorganic phosphorus was determined by the method of Gomoria [18] by Mr. C. E. Downs.

6. *Amions.*—Serum sodium was determined by the method of Consolazio and Dill,[19] serum potassium by the method of Consolazio and Talbott,[20] and serum calcium by the method of Clark and Collip modified by C. E. Downs.

OBSERVATIONS

1. *pH.*—The average blood pH of 10 dogs prior to cooling was 7.35, and at 20 C. it was 7.03. This represents an average drop of 0.016 units per degree Centi-

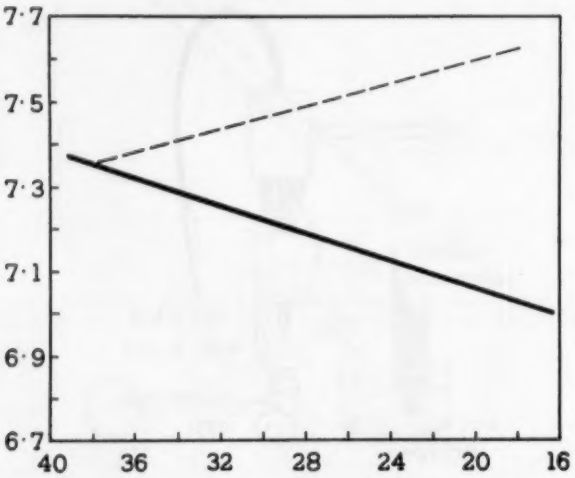


Fig. 4.—pH changes of blood cooled in vivo (solid line) and in vitro (broken line).

grade drop (solid line in Fig. 4). This change is opposite to the in vitro change towards alkalinity on cooling (broken line in Fig. 4).

2. *Carbon Dioxide.*—Retention of carbon dioxide is shown by an elevation of the CO_2 content of the plasma from 22 mEq./liter at normal body temperature to 30 mEq./liter at 20 C. in these 10 dogs. The pCO_2 rose from 45 to 130 mm. Hg. This change is obviously due to two factors, the diminished respiration and the increased solubility of carbon dioxide in blood at lowered body temperature.

3. *Cations.*—There was little significant change in any of the other cations measured, namely the chlorides, inorganic phosphorus, and lactic acid level; ketone bodies were not found.

4. *Anions.*—Likewise, there was no significant change in the concentration of sodium, potassium, calcium, and magnesium.

Figure 5 summarizes the changes in the acid-base pattern in the blood, after the manner of Gamble.[21] It is obvious that this is an uncompensated acidosis, mainly

gaseous in origin. This may be due to inadequate pulmonary ventilation, cardiopulmonary pathology, or carbonic anhydrase inhibition due to lowered temperature.

Having thus established the occurrence of an uncompensated gaseous acidosis with this particular method of cooling, we then set about to question its significance. Was this acidosis the cause of the cardiac irregularities and ventricular fibrillation that sometimes occur at lowered body temperature? Is the accumulation of carbon dioxide responsible for the lowering of blood pressure, which often occurs, and for other toxic effects? We could gain insight into the answers to these questions only by preventing the acidosis. This was attempted in two ways: (*a*) administration of base and (*b*) increased pulmonary ventilation.

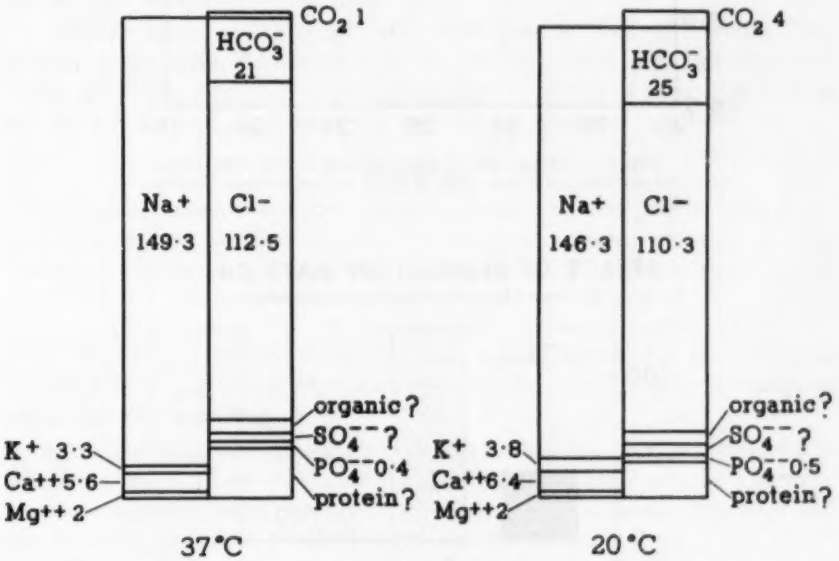


Fig. 5.—Acid-base balance of blood in routine hypothermia at 37 and 20 C.

Administration of Base.—In 20 dogs sodium bicarbonate was given intravenously during cooling, in divided doses totalling 100 mg. per kilogram of body weight. This tempered the acidosis so that the average drop in pH was only 0.009 units per degree Centigrade decrease, as compared with 0.016 units per degree in dogs not receiving base, but the mortality rate and frequency of cardiac irregularities was not altered significantly.

Increased Ventilation.—The second approach to the problem of preventing acidosis proved more successful. Although our method of giving artificial respiration was adequate in terms of oxygen saturation of the blood, we decided to increase the pulmonary ventilation and determine the effect of this upon the carbon dioxide content of the plasma. Accordingly, from the moment the dog was anesthetized until the termination of the experiment, endotracheal oxygen was given under strong positive pressure at a rate varying from 10 to 20 breaths a minute, the flow of

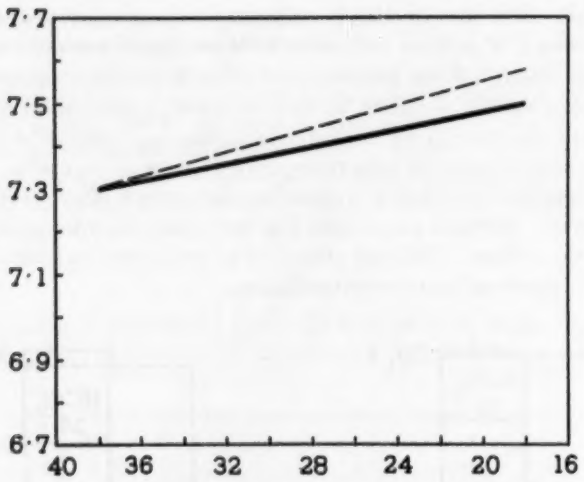


Fig. 6.—Average pH of blood of dogs cooled with forced respiration (solid line) and of blood cooled in vitro (broken line).

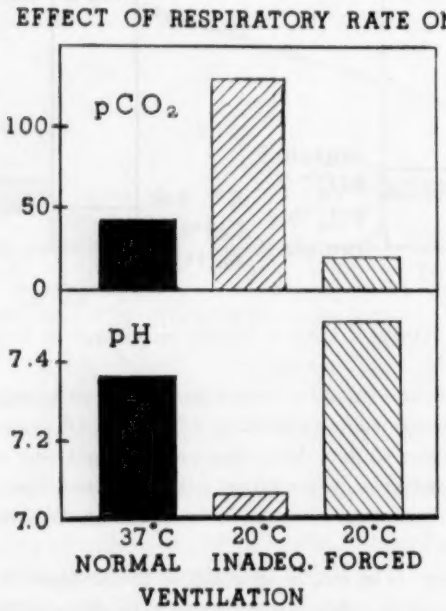


Fig. 7.—Summarizing changes that occur in blood pH and CO_2 content during routine hypothermia (center columns) and hypothermia with forced ventilation (right columns).

oxygen from the tank being 5 to 7 liters a minute, and the duration of positive pressure being approximately 40% of each breath.

It was found that by this means the blood pH could be kept constant or made to rise, with a simultaneous decrease in the carbon dioxide content of the plasma.

Figure 6 shows the average blood pH values for six dogs thus treated. It may be seen that the pH rises approximately 0.01 units per degree Centigrade decrease in temperature. This is close to the slope of the line for pH of blood cooled in vitro, which is represented by the broken line on the graph.

The carbon dioxide content could be kept constant or decreased, and in these six dogs it decreased from an average of 22 to 17 mEq./liter. The pCO_2 decreased slightly (45 mm. Hg at normal body temperature and 19 mm. Hg at 20 C.). These changes are summarized in Figure 7.

Although minor cardiac irregularities were noted in three of these six dogs, ventricular fibrillation did not occur in any, and these dogs seemed to do slightly better than the acidotic ones. In our small series two-thirds of those dogs with an elevated pH survived, as compared to one-third of those with a lowered pH.

COMMENT

This study demonstrated that changes in blood pH occur during cooling and that these changes are best controlled by the rate of positive-pressure artificial respiration with oxygen. Although in a small series of dogs there was no ventricular fibrillation and a higher survival rate when the pH was maintained above normal, we have not yet followed this with experiments to determine optimum pH for survival. The clinical application of this work would suggest that the patient be intubated early and a normal respiratory rate with good filling of the lungs be maintained during cooling.

In one human patient successfully cooled by Dr. Bigelow recently, extrasystoles, which had developed during the early stages of cooling under sedative and spontaneous respiration, were eliminated by passage of an intratracheal catheter and the institution of positive-pressure respiration with oxygen.

SUMMARY

This study was designed to investigate the acid-base balance of the blood in dogs during cooling and to determine whether any pH changes observed were related to the occurrence of ventricular fibrillation and cardiac standstill.

The determination of blood pH in an animal at low body temperature presents certain technical difficulties which are discussed.

Various blood gases, electrolytes, and organic acids have been measured. There is a marked variation in the amount of free CO_2 dissolved in the blood, depending on the amount of pulmonary ventilation. There is little significant change in the other anions or cations of the blood.

The pH of blood in vitro rises 0.017 units per degree Centigrade of cooling. The pH of blood in vivo during hypothermia may be varied depending on the rate of positive-pressure respirations with oxygen, or, less effectively, by administration of alkali.

The maintenance of a pH above normal during cooling was associated with a reduced incidence of ventricular fibrillation and a better survival rate.

This study was done under the direction of Dr. W. G. Bigelow in conjunction with other studies in hypothermia.

REFERENCES

1. Hastings, A. B., and Sendroy, J.: Studies of Acidosis: XIX. The Colorimetric Determination of Blood pH at Body Temperature Without Buffer Standards, J. Biol. Chem. **61**:695-710, 1924.

2. Cullen, G. E.: The Colorimetric Determination of the Hydrogen Ion Concentration of the Blood Plasma, J. Biol. Chem. **52**:501-515, 1922.

3. Martin, C. J., and Lepper, E. H.: The Influence of Temperature on the pH of Blood, Biochem. J. **20**:1071-1076, 1926.

4. Harvard, R. E., and Kerridge, P. T.: An Immediate Acid Change in Shed Blood, Biochem. J. **23**:600-607, 1929.

5. Lang, E. P.: The Application of the Quinhydrone Electrode to the Determination of the pH of Serum and Plasma, J. Biol. Chem. **88**:551, 1930.

6. Rosenthal, T. B.: The Effect of Temperature on the pH of Blood and Plasma in Vitro, J. Biol. Chem. **173**:25-30, 1948.

7. Stormont, R. J.; Foster, M. A., and Pfeiffer, C.: Plasma pH, CO_2 Content of the Blood, and Tissue Gas Tensions During Hibernation, Proc. Soc. Exper. Biol. & Med. **42**:56-59, 1939.

8. Kayser, C. H.: Exchanges Respiratoires du Loir pendant le Sommeil Hibernal, Compt. rend. Soc. biol. **128**:85-88, 1938.

9. Dubois, R.: Carbonic Autonarcosis, Compt. rend. Soc. biol. **149**:814, 1895.

10. Dill, D. B., and Forbes, W. H.: Respiratory and Metabolic Effects of Hypothermia, Am. J. Physiol. **132**:685-697, 1941.

11. Talbott, J. H.; Consolazio, W. V., and Pecora, L. J.: Hypothermia, Report of a Case, Arch. Int. Med. **68**:1120-1132, 1941.

12. Lange, K.; Weiner, D., and Gold, M. M. A.: Studies on the Mechanism of Cardiac Injury in Experimental Hypothermia, Ann. Int. Med. **31**:989-1002, 1949.

13. Bigelow, W. G.; Lindsay, W. K.; Harrison, R. C.; Gordon, R. A., and Greenwood, W. F.: Oxygen Transport and Utilization in Dogs at Low Body Temperatures, Am. J. Physiol. **160**:125-137, 1950.

14. Bigelow, W. G.; Lindsay, W. K., and Greenwood, W. F.: Hypothermia, Its Possible Role in Cardiac Surgery: An Investigation of Factors Governing Survival in Dogs at Low Body Temperatures, Ann. Surg. **132**:849-866, 1950.

15. Singer, R. B., and Hastings, A. B.: An Improved Clinical Method for the Estimation of Disturbances of the Acid Base Balance of Human Blood, Medicine **27**:223-242, 1948.

16. Asper, S. P.; Schales, O., and Schales, S. S.: Importance of Controlling pH in the Schales and Schales Method of Chloride Determination, J. Biol. Chem. **168**:779-780, 1947.

17. Barker, S. B., and Summerson, W. H.: Colorimetric Determinations of Lactic Acid in Biological Material, J. Biol. Chem. **138**:535, 1941.

18. Gomoria, G.: A Modification of the Colorimetric Phosphorus Determination for Use with the Photoelectric Colorimeter, J. Lab. & Clin. Med. **27**:955, 1942.

19. Consolazio, W. V., and Dill, D. B.: The Determination of Sodium, J. Biol. Chem. **137**:587, 1941.

20. Consolazio, W. V., and Talbott, J. H.: Modification of the Method of Shohl and Bennett for the Determination of Potassium in Serum and Urine, J. Biol. Chem. **126**:55, 1938.

21. Gamble, J. L.: The Chemical Anatomy, Physiology and Pathology of Extracellular Fluid, Ed. 5, Cambridge, Mass., Harvard University Press, 1947.

CARCINOIDS OF APPENDIX AND GASTROINTESTINAL TRACT

WARD D. O'SULLIVAN, M.D.
AND
JOHN J. BOWE, M.D.
NEW YORK

THE PECULIAR nature of the carcinoid group of tumors has prompted this survey of our experience with these tumors at the New York Hospital. Carcinoids have always evoked a great deal of interest because of their unique character. Histologically they appear the same regardless of their gross anatomic position, yet the decision whether or not they are benign depends more on their anatomic location than their histologic appearance. Appendiceal carcinoids are customarily considered benign, whereas carcinoids elsewhere are looked upon as malignant. The cases herein reported represent a 20-year experience, from 1932 to 1952. The great majority were from the surgical service of the New York Hospital, a few from the gynecological service, and two additional such tumors were found incidentally at necropsy. Though several series of carcinoids have been reported recently, we feel that it is worth while to report our experience at the New York Hospital-Cornell Medical Center.

Since the original description by Obendorfer of the appendiceal carcinoid, the relative benignity of this lesion has been accepted. The parent cell of this tumor has been generally considered to be the Kulschitsky cell, an argentaffin situated in the lining of the intestinal mucosa, as postulated by Masson. Carcinoids may therefore arise anywhere in the alimentary tract, from stomach to rectum. They are commonest, however, in the appendix. Their argentaffin properties and rather regular microscopic appearance make their identification relatively easy.

Thirty-eight carcinoid tumors constitute this series. Twenty-eight of these were located in the appendix (Table 1), and the remaining 10 tumors were situated in various sites elsewhere in the gastrointestinal tract (Table 2). Twenty-three patients were females, and 15 were males. This ratio agrees with the experience of others, who report a greater incidence in females.[1] The age incidence was 8 to 78 years, with the majority of cases occurring in the third and fourth decades of life.

The incidence of carcinoid of the appendix was 0.32% of all operatively removed appendices. This falls well within the 0.2 to 0.5% incidence quoted in the literature.* Symptoms of acute or chronic appendicitis were the presenting complaints in 17, or 61%, of these cases. In the remaining 11, or 39%, the appendix was incidentally removed at laparotomy performed for other disease. Of interest is the fact that most of these tumors were not recognized as such at the operating table and only in later examination by the pathologist was their true nature revealed

From the Department of Surgery of The New York Hospital-Cornell Medical Center.
* References 1 and 2.

TABLE 1.—*Carcinoids of the Appendix*

Case	N. Y. H. No.	Sex	Age, Yr.	Year	Location of Tumor	Symptoms	Preoperative Diagnosis	Gross Pathology	Pathological Diagnosis	Follow-Up
1	19908	F	29	1923	Appendix	Abdominal discomfort, 7 yr.	"Duodenal stasis"	1.3 cm. swelling at appendiceal tip	Carcinoid of appendix; endometriosis of appendix	16 yr., living and well
2	35778	F	25	1923	Appendix	RLQ pain, 1 yr.	Chronic appendicitis	Tip of appendix obliterated by tumor	Carcinoid of appendix	3 yr., living and well
3	55234	M	19	1934	Appendix	RLQ pain, 12 hr.	Acute appendicitis	Fibrous appendix with areas of thickening	Acute suppurative appendicitis; carcinoid of appendix	None
4	73197	F	29	1934	Appendix	Gall bladder symptoms	Chronic cholecystitis and cholelithiasis	.....	Diffuse early carcinoid of appendix; cholelithiasis	18 yr., living and well; has deformed duodenal bulb on x-ray
5	54322	F	26	1934	Appendix	Abdominal pain, 1 mo.	Chronic appendicitis	Nodule at tip of appendix	Carcinoid of appendix	None
6	189997	F	26	1937	Appendix	Intermittent pain, 5 yr.	Chronic appendicitis	Long thickened appendix	Fibrous appendix; carcinoid of appendix	None
7	163797	F	30	1937	Appendix	Dysmenorrhea	Retroversion uterus and endometriosis	Distal end filled with yellow tumor	Carcinoid of appendix	15 yr., living and well
8	182591	F	34	1937	Appendix	RLQ pain, 6 wk.	Chronic appendicitis	Lumen obliterated by yellow cord which ran the length of the organ	Carcinoid of appendix	None
9	145383	F	23	1938	Appendix	Abdominal pain, 24 hr.	Acute appendicitis	.....	Acute suppurative appendicitis; carcinoid of appendix	4 yr., living without G. I. symptoms; has pulmonary tuberculosis
10	245755	F	48	1939	Appendix	RLQ pain, 5 days	Subsiding acute appendicitis	Tip of appendix greyish	Carcinoid of appendix	14 yr., living and well
11	273567	F	22	1940	Appendix	RLQ pain, 1 yr.	Recurrent appendicitis	Normal appendix	Carcinoid of appendix	None
12	313377	F	25	1941	Appendix	RLQ pain, 1 day	Mild acute appendicitis	Distal 5 cm. orange and fatty in consistency	Carcinoid of appendix; mild acute inflammation	5 yr., living and well
13	300565	F	8	1941	Appendix	Abdominal pain, 14 hr.	Acute appendicitis	Obstructing tumor in midportion of appendix	Carcinoid of appendix with obstruction and perforation	None
14	329690	M	13	1942	Appendix	RLQ pain, 1 day	Acute appendicitis	9 mm. yellow ulcerated area 3 cm. from tip	Acute diffuse suppurative appendicitis; carcinoid of appendix	11 yr., living and well

15	315467	F	41	1942	Appendix	Gall bladder symptoms	Chronic cholecystitis and cholelithiasis	Bulbous tip, several subserosal yellow spots	Carcinoid of appendix; cholelithiasis	4 yr., living and well
16	71469	M	12	1942	Appendix	RLQ pain, 6 hr.	Acute appendicitis	Narrow fibrous appendix	Acute appendicitis; carcinoid of appendix	None
17	153698	M	15	1942	Appendix	Abdominal pain, 2 days	Acute appendicitis	Bulbous yellow tip	Carcinoid of appendix	None
18	337513	M	70	1942	Appendix	Abdominal pain, constipation, weight loss	Ca. of ascending colon	Club-shaped appendix	Adenocarcinoma of colon; carcinoid of appendix; mucosal polyp of cecum	Died 3 yr. post-op. presumably of carcinoma
19	360649	M	43	1943	Appendix	Abdominal pain, 3 mo.	Questionable sigmoid lesion	Yellow bulbous tip to appendix	Chronic lymphoid appendicitis; carcinoid of appendix	None
20	411089	F	16	1945	Appendix	RLQ pain, 12 hr.	Acute appendicitis	Acutely inflamed perforated appendix	Acute suppurative appendicitis with empyema complicating carcinoid of appendix	None
21	441914	F	17	1946	Appendix	Intermittent abdominal pain, 1 yr.	Chronic appendicitis	Yellow bulbous tip to appendix	Carcinoid of appendix	2 yr., living and well
22	229784	F	39	1947	Appendix	Dysmenorrhea	Retroversion of uterus	Firm yellow nodule projecting into lumen	Carcinoid of appendix	None
23	221244	M	46	1948	Appendix	Abdominal pain, 2 days	Acute appendicitis	Normal appendix	Carcinoid of appendix	None
24	529052	F	58	1949	Appendix	Gall bladder symptoms, weight loss	Chronic cholecystitis and cholelithiasis; sarcoidosis	Yellow nodule	Carcinoid of appendix; cholelithiasis	Died within 1 yr. of sarcoidosis
25	558150	F	58	1949	Appendix	Abdominal pain 3 yr., loss of 22 lb. (9.9 kg.)	Carcinoma of cecum	Wall of appendix replaced with yellow-white tumor	Argentaffin carcinoma of appendix with metastasis to liver, pancreas, lymph node, ovary, broad ligament, and peritoneum	Death in hospital
26	595796	M	63	1951	Appendix	RLQ pain, 48 hr.	Acute appendicitis	Acutely inflamed appendix with perforation at tip	Acute appendicitis with perforation; carcinoid of appendix	2 yr., living and well
27	602683	F	43	1951	Appendix	Abdominal mass	Myoma uteri	Thickened tip and occluded lumen	Carcinoid of appendix with invasion of mesoappendix; myoma uteri	1 yr., living and well
28	606327	F	35	1951	Appendix	Abdominal pain, urinary frequency	Myoma uteri	Obliterated lumen in distal ⅓	Carcinoid of appendix; myoma uteri	2 yr., living and well

TABLE 2.—*Carcinoids in Sites Other Than the Appendix*

Case	N. Y. H. No.	Sex	Age, Yr.	Year	Location of Tumor	Symptoms	Preoperative Diagnosis	Gross Pathology	Pathological Diagnosis	Follow-Up
29	12806	M	54	1940	Gastrocolic omentum	Epigastric pain	Chronic peptic ulcer	Hard white mass	Carcinoid, metastatic	None
30	319274	M	43	1942	Primary site undetermined; liver and peritoneal metastases	Abdominal discomfort, 5 mo.; jaundice, 2 wk.	Ca. of pancreas	Stony hard mass	Metastatic carcinoid	Died, 1½ yr. postoperatively
31	489314	M	67	1947	Transverse colon	Abdominal pain and diarrhea, 1 yr.	Ca. of colon	Annular lesion of transverse colon	Carcinoid of transverse colon	6 yr., living and well
32	513309	F	58	1948	Cecum with metastases to peritoneum, liver, and omentum	Diarrhea and weight loss, 1 yr.	Ca. of uterus with liver metastases	Annular lesion of cecum	Carcinoid of cecum with metastases to liver and omentum	Died in hospital
33	551987	F	75	1949	Rectum	Constipation, tenesmus, 1 mo.	Ca. of rectum	Annular tumor of rectum	Carcinoid of rectum with lymphatic metastasis	Died, 1 yr. postoperatively
34	586719	M	63	1950	Duodenum	Epigastric pain, vomiting	Posterior penetrating duodenal ulcer	Edematous duodenum	Chronic ulcer of duodenum; carcinoid of duodenum	6 mo., living; in sanitorium with pulmonary tuberculosis
35	238881	M	78	1951	Terminal ileum	Abdominal pain, 1 day; anorexia	Acute appendicitis	Polyp of ileum	Carcinoid of ileum	2 yr., living; hemiparesis
36	490602	F	59	1951	Multiple of ileum with metastases to liver and mesenteric lymph nodes	Intermittent abdominal pain, 2 yr.	Partial small bowel obstruction	Annular lesion of ileum, 4 polypoid lesions of ileum	Carcinoid, multiple of ileum with metastases to liver and lymph nodes	2 yr., living with evidence of residual tumor
						Incidental Autopsy Findings				
37	449563	M	68	1946	Rectum	Incidental finding of submucous carcinoid at autopsy; patient died of myocardial infaret				
38	358802	M	53	1947	Ileum	Incidental finding of submucous carcinoid at autopsy; patient died of myocardial infaret				

(Fig. 1). Most of these growths occurred in the distal third of the appendix. Occasionally, however, they may be present at the base of the appendix, and when this occurs some degree of obstruction of the organ may follow. This may be manifested as a mucocele [3] but more often may lead to symptoms of acute appendicitis. In two of our cases, Cases 13 and 20, the tumor was definitely obstructing the appendiceal lumen and doubtless was a factor in the acute inflammation and perforation present in these two cases.

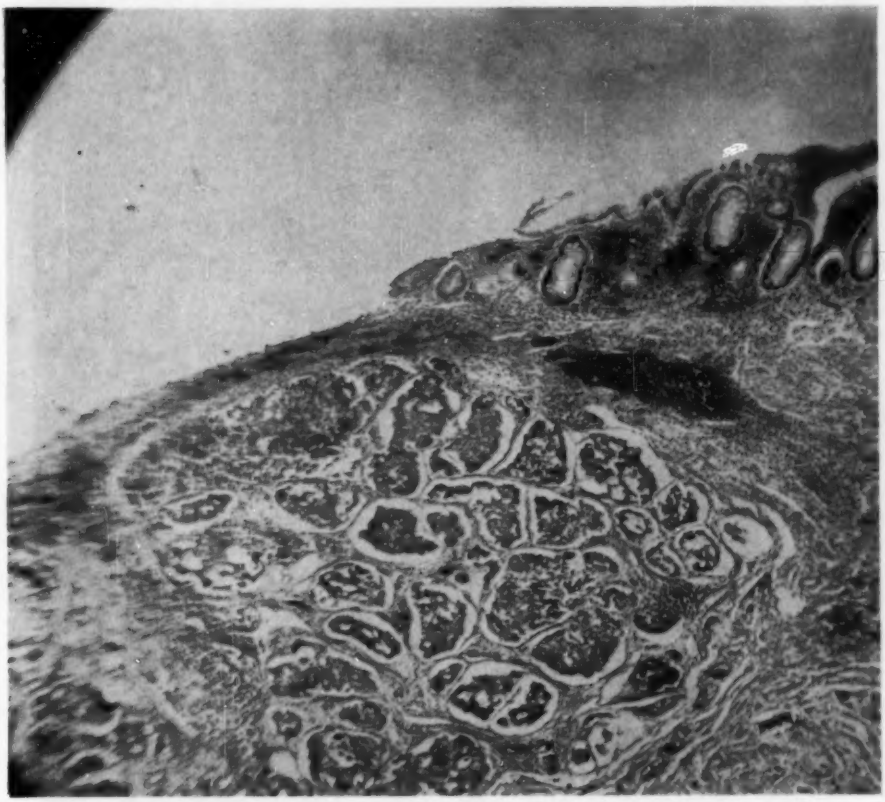


Fig. 1.—Localized carcinoid in appendix which is acutely inflamed.

In this group of 28 appendiceal carcinoids 26 were treated by simple appendectomy. The follow-up is not complete, but to our knowledge there has been no recurrence in these cases. The tumors are considered totally eradicated. The remaining two cases of appendiceal carcinoids deserve separate mention. In 1946 Reitz [4] reported the 22d case of metastasizing appendiceal carcinoid. Subsequently, another similar case was reported by Altman and Mann [5] in 1946. The two in our series are reported briefly below.

CASE 25.—G. V., N. Y. H. No. 558 150, a 58-year-old woman, entered the hospital because of intermittent abdominal pain which had troubled her for three years. She had lost 22 lb. (9.9 kg.) in the three months before admission.

Physical Examination.—B. P. 200/100. There was a Grade II systolic murmur at the cardiac apex transmitted over the entire precordium. The liver edge was palpable four fingerbreadths below the right costal margin. In the right iliac fossa was a poorly defined mass, 6 by 8 cm. in size, slightly tender, and not movable. On rectal examination several firm shotty nodules 1 cm. in diameter could be felt in the cul-de-sac. An x-ray demonstrated an obstruction in the right side of the colon.

Laboratory Data.—Hemoglobin 10 gm.; RBC 3,580,000. Test of stools was positive for occult blood.

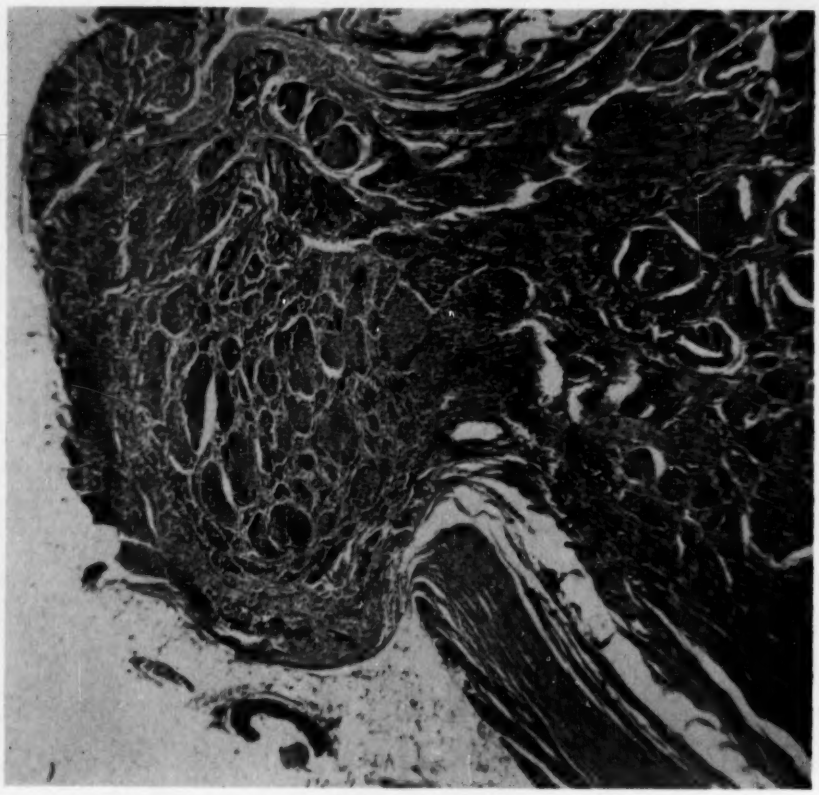


Fig. 2 (Case 27).—Tumor growing through the appendiceal wall.

Course.—The working diagnosis was carcinoma of the ascending colon, and accordingly the patient was prepared for intestinal surgery. On her fifth hospital day she had a generalized convulsion and lost consciousness. She remained comatose until she died on her 37th hospital day. Death was attributed to a cerebrovascular accident. At autopsy an argentaffin carcinoid of the appendix with metastases to the liver, lymph nodes, pancreas, ovary, and broad ligament was discovered. No tumor was found in the brain.

CASE 27.—A. C., N. Y. H. No. 602 683, a 43-year-old woman, was admitted to the gynecological service because of frequency and urgency of urination for many years. Physical examination revealed an abdominal mass arising from the pelvis, presumably from the uterus,

and extending to the umbilicus. There were no other pertinent physical findings. Laboratory data were unremarkable. At operation a large myomatous uterus was removed and an incidental appendectomy performed.

The pathologist reported the presence of an appendiceal carcinoid that was invading the mesoappendix (Figs. 2 and 3). Therefore, 18 days after the initial operation a right hemicolectomy was done. No tumor was found in the resected specimen. The patient is alive and asymptomatic at present, 18 months after operation.

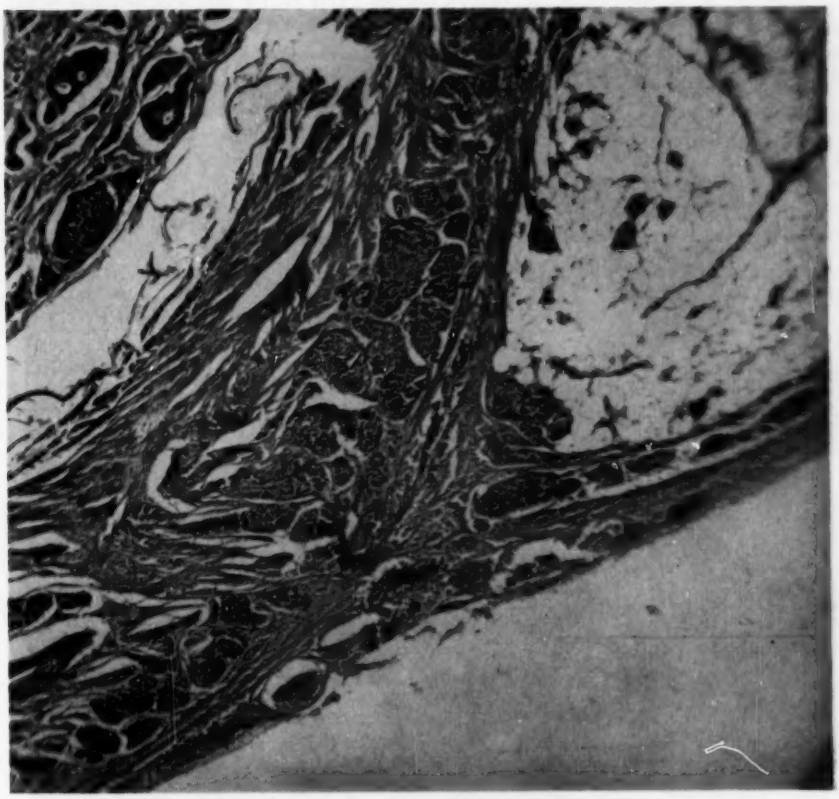


Fig. 3 (Case 27).—Tumor cells in the fat of the mesoappendix.

Here are two instances of malignant appendiceal carcinoids. One was frankly so, with widespread metastases; the other showed locally invasive characteristics consistent with malignant disease. These two cases represent 7% of the appendiceal carcinoids in this series.

Of the remaining 10 tumors 4 were in the small intestine, 1 in the duodenum, and 3 in the ileum; 4 were in the large bowel, 1 in the cecum, 1 in the transverse colon, and 2 in the rectum. In the other two instances the primary site was never determined.

The duodenal carcinoid was found in the surgical specimen removed by subtotal gastric resection for duodenal ulcer. It was a small lesion, but study of the micro-

scopic section revealed tumor cells in the periarterial lymphatics. Unfortunately, no adequate follow-up on this patient is available.

The character of the three ileal carcinoids varied greatly. One was an incidental autopsy finding. It was 3 mm. in diameter and no metastases were present. One was a simple polyp. The third was a case of multiple primary lesions in the ileum with lymphatic and hepatic metastases. These latter two cases are recorded in brief.

CASE 35.—F. J., aged 78, N. Y. H. No. 238 881. This elderly man was admitted to the New York Hospital on May 8, 1951, with an eight-hour history of crampy abdominal pain.

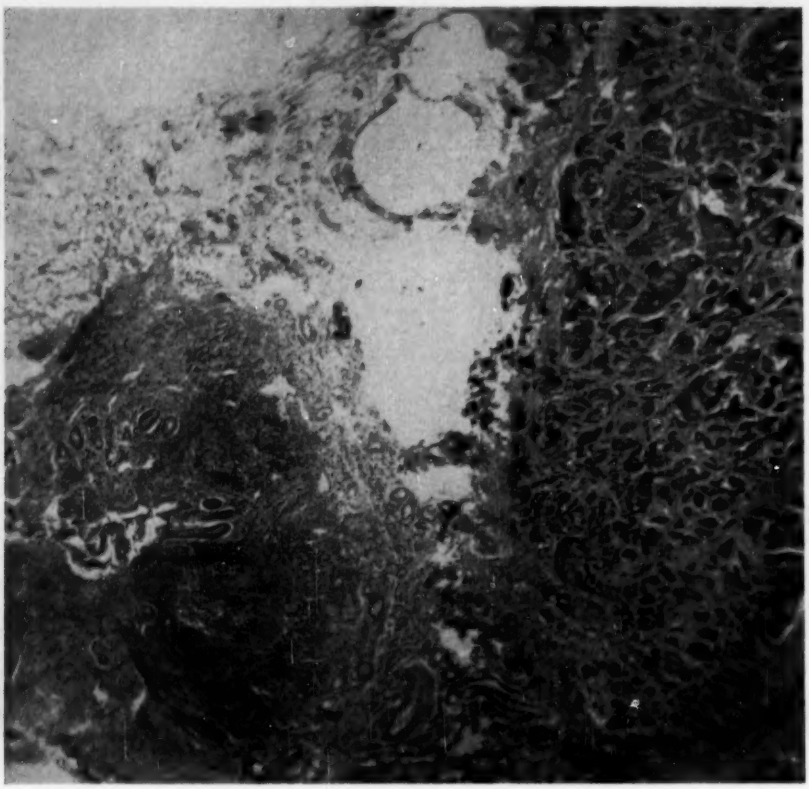


Fig. 4 (Case 36).—Malignant carcinoid of ileum with ulceration and infection.

He appeared his age of 78 years. His temperature was 38.3 C.; blood pressure was 220/94. There was marked tenderness in the right lower quadrant of the abdomen.

A preoperative diagnosis of acute appendicitis was made, and operation was performed. A normal appendix was found. Exploration revealed a small polyp 1 cm. in diameter in the terminal ileum. The appendix was removed and a polypectomy done. The polyp was a carcinoid.

The patient's postoperative course was prolonged, being complicated by a left hemiplegia. He was discharged 22 days after operation. Fourteen months later he still had the residue of his hemiplegia but had no symptoms referable to his intestinal tract other than mild constipation.

CASE 36.—C. R., N. Y. H. No. 596 662, a 59-year-old woman, was admitted to the New York Hospital on April 25, 1951, because of intermittent abdominal pain of two years' duration.

In the three months preceding admission she had lost over 20 lb. (9 kg.). Her liver was enlarged, her stools contained occult blood, and a gastrointestinal x-ray series showed irregularity and dilatation of the ileum. At operation, on May 11, 1951, an encircling obstructing lesion of the ileum was found (Figs. 4 and 5). Distal to this four small polypoid tumors were palpable (Fig. 6). There was metastatic tumor in the liver and in the mesenteric nodes (Fig. 7) and many metastatic seedings throughout the peritoneal cavity. Two feet (0.6 meter) of ileum, including all the intrinsic lesions, were resected as a palliative procedure and an end-to-end anastomosis performed.

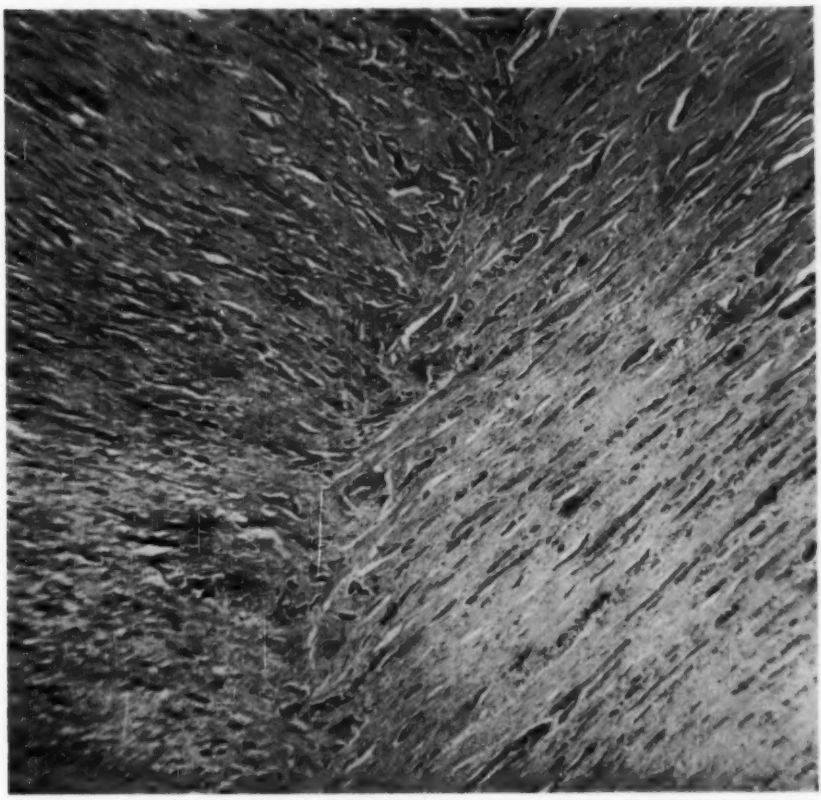


Fig. 5 (Case 36).—Malignant carcinoid of ileum. Tumor cells may be seen deep in muscular layer of the ileal wall.

The patient's postoperative course was essentially benign, and when seen 12 months after operation she was asymptomatic and working. She had regained her normal weight. Her liver was large, and a firm mass was palpable in the right lower quadrant of her abdomen. There was suggestion of peritoneal implants in her cul-de-sac.

In the group of large bowel carcinoids are two rectal lesions. One was an incidental autopsy finding in a patient dying of myocardial infarction and was an isolated lesion only 3 mm. in diameter (Fig. 8). It had caused no symptoms. The other patient, 75 years of age, Case 33, had typical symptoms of rectal cancer, i. e., constipation, diarrhea, and rectal pain.

CASE 33.—M. C., aged 75, N. Y. H. No. 551 987. This elderly woman entered the New York Hospital with a two-month history of rectal pain and alternating diarrhea and constipation. A large mass could be felt in the rectum 5 cm. superior to the anus. A combined abdominoperineal resection of the rectum with terminal sigmoidostomy was performed on Sept. 30, 1949. A firm node, located at the origin of the superior hemorrhoidal artery, was removed in continuity with the specimen. The pathologist reported a rectal carcinoid with a metastasis to the lymph node. After a slow convalescence, the patient was discharged. She was later admitted to a nursing home, where she died 14 months after operation from a recurrence of her tumor.

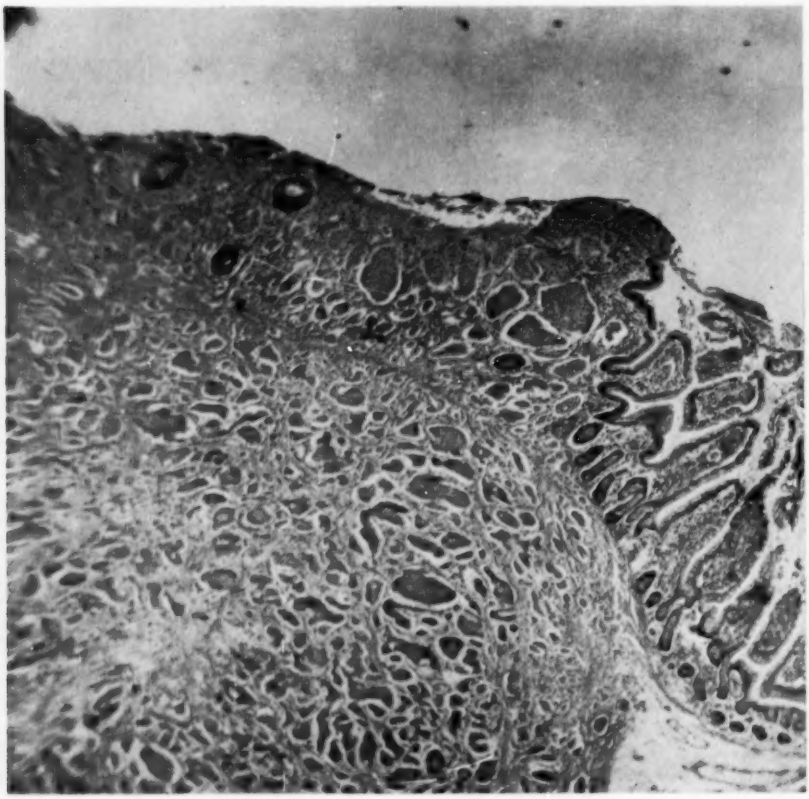


Fig. 6 (Case 36).—Submucosal carcinoid located in the ileum distal to the larger and obstructing lesion shown in Figures 4 and 5.

Of the remaining large bowel lesions one was in the cecum and the other in the transverse colon. The patient with the cecal lesion (Case 32) was in extremis on admission and died after intestinal decompression necessitated by her intestinal obstruction. At autopsy widespread metastases were found. The other patient (Case 21) had a large local lesion of the transverse colon without metastases. This was resected, and the patient is well and without evidence of recurrence six years after operation.

The final two cases are examples of carcinoids presenting as metastatic foci without a demonstrated primary lesion.

Case 29.—C. V., N. Y. H. No. 12896, a 54-year-old man, was admitted to the New York Hospital on Sept. 5, 1940, because of duodenal ulcer. He had had several major episodes of gastrointestinal hemorrhage in the past, the first 23 years before this admission. This time he was admitted because of persistent vomiting. He was a middle-aged man appearing chronically ill. Gastrointestinal series showed an obstructed stomach. His gastric acidity was above normal levels. On Sept. 6, 1940, a gastroenterostomy was done for what appeared to be a typical stenosing duodenal ulcer. At the completion of the operation a 5 cm. white hard mass was noticed in the gastrocolic omentum. Exploration revealed two smaller similar masses also in

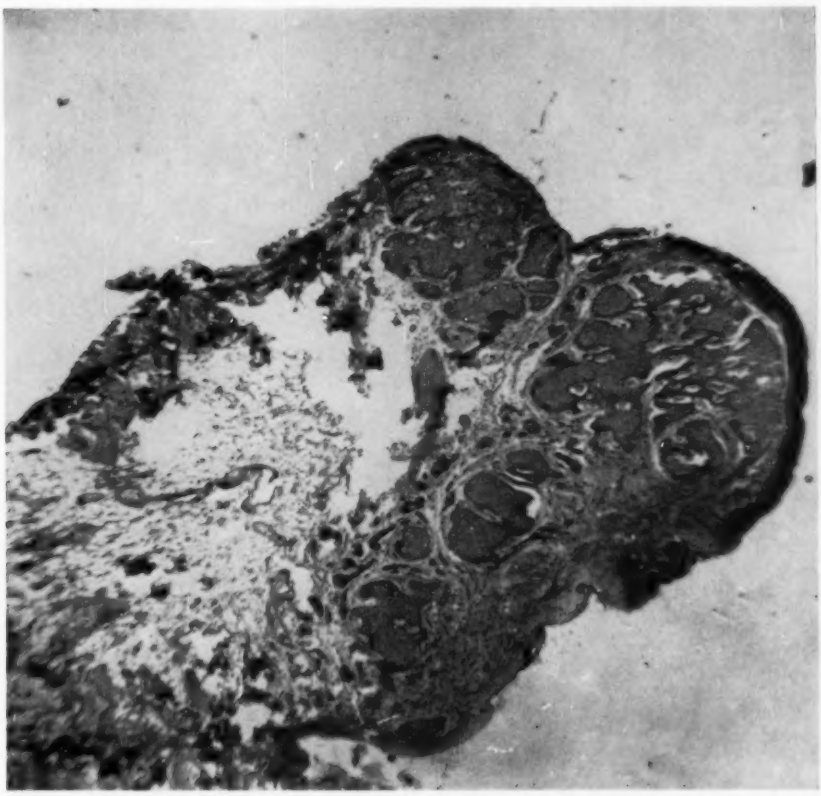


Fig. 7 (Case 36).—Metastatic carcinoid in mesenteric lymph node. Primary lesion was in ileum.

the gastrocolic omentum. A 10 cm. mass was seen in the gastrohepatic omentum. Exploration of the entire gastrointestinal tract at the time of operation disclosed no primary lesion. The most readily accessible mass was excised as a biopsy. It was a carcinoid containing spicules of bone (Fig. 9). Regrettably, no follow-up is available.

Case 30.—O. M., N. Y. H. No. 319 274, a 43-year-old man, entered the New York Hospital on Jan. 20, 1942, because of jaundice. Three months previously he had gone to a physician because of difficulty with his eyes. When he was examined he was told he had an abdominal mass. He then began to notice excessive flatulence; his stools became pale and bulky. Immediately before admission jaundice and pruritus of the skin were apparent. When admitted his sclerae and skin were icteric. The skin was excoriated in many places. The liver edge was one finger's

breadth below the costal margin. A hard movable mass was palpable to the right of and superior to the umbilicus. The gall bladder was not palpable. A small mass could be felt in the cul-de-sac on rectal examination. The patient was not anemic. At operation on Jan. 23, 1942, a stony hard movable mass was found in the body of the pancreas extending laterally toward the head of the pancreas. The gall bladder and common duct were dilated. Metastatic nodules were present in the liver and throughout the peritoneal cavity. A cholecystogastrostomy was accomplished and a peritoneal implant removed for biopsy. The operative diagnosis was carcinoma of the pancreas with metastases. On microscopic section the metastatic nodule was seen to be a typical carcinoid.

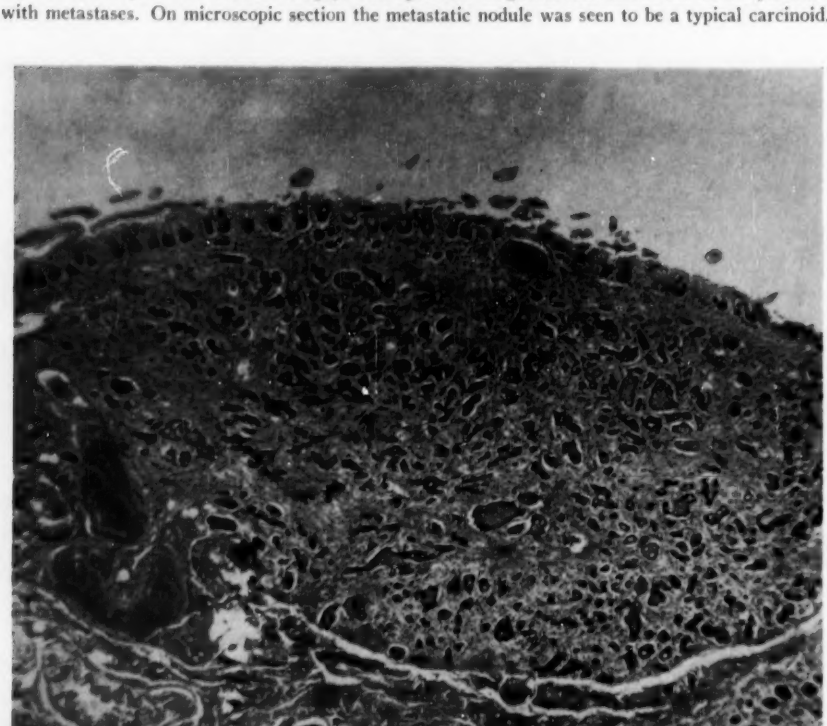


Fig. 8 (Case 37).—Rectal carcinoid. This was an incidental autopsy finding.

When last seen, one year after operation, the patient was moribund but was lost to follow-up thereafter.

COMMENT

Twenty-six of the 28 appendiceal carcinoids were treated by appendectomy alone. There has been no reason to regret this simple surgical treatment. Although our follow-up cannot be considered complete, there is no known instance of recurrence in this group.

Carcinoid of the appendix, however, can be a frankly malignant tumor. One patient (Case 25) had widespread metastases at the time of her hospitalization and

was beyond surgical help. Recognizing this possibility, accurate study of the excised appendix must be done to detect the occasional carcinoid that is potentially malignant. We believe that Case 27 represents such an instance. Local infiltration beyond the confines of the appendix proper is adequate evidence that the tumor is essentially malignant, and radical surgery should be undertaken without delay.

The four small bowel carcinoids in the series showed widely divergent characters, from simple polyp to obvious cancer. It may be argued that the argentaffin carcinoma

Fig. 9 (Case 29).—Metastatic carcinoid in gastrocolic omentum. In this section spicules of bone may be seen as well as the sheets of typical argentaffin cells.

(Case 36) had preexisted as a simple polyp and had undergone malignant change only after a period of time. Yet the tiny silent duodenal carcinoid had already entered the periarterial lymphatics and was obviously a malignant tumor. It would seem advisable to treat carcinoids of the small bowel as malignant disease from the very first. The same may be said of carcinoids of the large intestine.

In the two cases where metastases only were found, it would not seem imprudent to assume a primary lesion somewhere in the intestinal tract which had escaped detection. These two instances can best be used to illustrate the malignant character of intestinal carcinoids, even when they are small and defy detection.

SUMMARY

Thirty-eight cases of intestinal carcinoids are reviewed. Twenty-eight were in the appendix, and 26 of these were treated by simple appendectomy. Two were considered malignant, one because of demonstrated metastases, the other because of local invasion of the mesoappendix. Four carcinoids of the small bowel and four of the large bowel are reviewed. There were two instances in which metastatic tumor was found and no primary lesion was demonstrated.

REFERENCES

1. Weiss, G. N., and Hertzog, A. J.: Carcinoid Tumors of the Appendix: Review of 26 Cases, Surgery **30**:657-660, 1951.

2. Hopping, R. A.; Dockerty, M. B., and Masson, J. C.: Carcinoid Tumor of the Appendix: Report of a Case in Which Extensive Intra-Abdominal Metastases Occurred, Including Involvement of Right Ovary, Arch. Surg. **45**:613-622, 1942.

3. Weiner, J. J., and Sala, A. M.: Carcinoid Tumor of the Appendix Producing Mucocele, Am. J. Surg. **71**:420-422, 1946.

4. Reitz, C. B.: Carcinoids, Malignant Carcinoids and Carcinoma of Veriform Appendix, Hahneman. Monthly **81**:230-239, 1946.

5. Altman, V., and Mann, V.: Metastasizing Carcinoid Tumor of the Appendix and Cecum, Am. J. Surg. **76**:434-439, 1948.

INTRAVENOUS INFUSION OF COCONUT WATER

BEN EISEMAN, M.D.
DENVER

IN MANY of the underdeveloped areas of the world it is impossible locally to prepare solutions sufficiently pure to be employed for intravenous infusion. A major need, therefore, exists for an easily obtainable cheap source of sterile pyrogen-free fluid suitable for intravenous administration.

The purpose of this communication is to present laboratory and clinical data concerning coconut water as a possible source of such intravenous fluid. Should this material prove to be satisfactory, it might be of benefit both to physicians now practicing in remote areas and under emergency military conditions where the normal sources of intravenous solutions have been interrupted.

MATERIALS AND METHODS

This study has been carried out in Bangkok, Thailand, and in St. Louis. The majority of the laboratory procedures have been undertaken in St. Louis; clinical trials have been done in both Thailand and St. Louis. The present study deals only with coconut water of low fat content obtained from unripe green fruit.

Coconuts in Thailand were obtained from the local markets. Those investigated in the United States were grown in Miami, Fla., and shipped by air to St. Louis.* Cocos nucifera of between 170 and 220 days of age were used.

The husk at the stalk end of the green coconut is cut back, exposing the soft white meaty "eye" which runs from the stalk through the husk, penetrates the shell of the nut, and leads through the endosperm into the fluid-filled center of the fruit (Figs. 1, 2, and 3). The cut surface of the eye and husk are sterilized with alcohol and the coconut water aseptically withdrawn by inserting a large bore sterile cannula or needle through the eye into the fluid. Since the fluid is hermetically sealed, it is necessary to establish an air vent by passing a sterile needle through a portion of the eye adjacent to the drainage cannula. The coconut water is then filtered through a single sterile surgical gauze resting in a glass funnel and is collected in a blood donor bottle (Fig. 4). This filtration makes certain that no particles of endosperm or coconut meat are drained off with the fluid.

From the Department of Surgery, Washington University School of Medicine, and Barnes Hospital, St. Louis.

Associate Professor of Surgery, Colorado University School of Medicine, and Chief of Surgical Service, Veterans Administration Hospital, Denver.

*Mr. A. D. Barnes, Director of the Dade County Park Department, Miami, Fla., supplied the coconuts used in St. Louis.

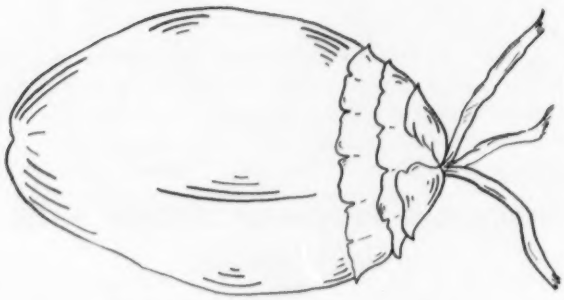


Fig. 1.—Husk at end of green coconut.

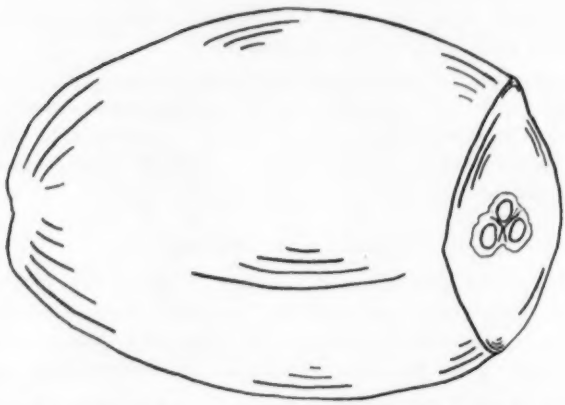


Fig. 2.—Husk at stalk end of coconut cut back to expose soft "eye."

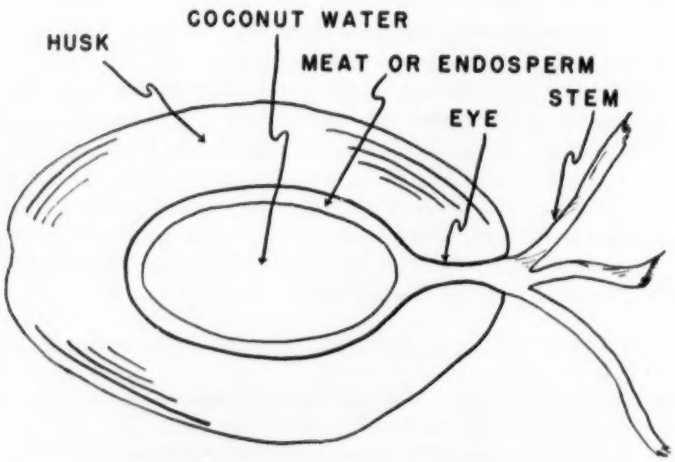


Fig. 3.—Cross section of coconut.

BACTERIOLOGICAL STUDIES

Ten samples of coconut water removed aseptically were cultured on broth and incubated at 37 C. for 72 hours. These same 10 samples were cultured on Saboroud's medium, incubated at 37 C. for 10 days, and examined for evidence of fungus growth. Anaerobic cultures were made by planting these samples of freshly drawn coconut water in thioglycolate broth and incubating for 72 hours at 37 C.

Fig. 4.—Coconut water being filtered through sterile gauze in glass funnel and collected in blood donor bottle.

Additional tests were made for anaerobic organisms by innoculating blood agar plates and incubating at 37 C. for 72 hours in a Varney jar.

In no instance was there aerobic, anaerobic, bacterial, or fungus growth in the freshly drawn coconut water. Several samples from cracked nuts showed signs of bacterial and fungal contamination.

Coconut water is a good bacterial medium, for even the slightest break in aseptic technique resulted in luxuriant bacterial growth.

HEMATOLOGIC STUDIES

Twelve samples of coconut water were tested for hemolytic activity. A 20% suspension of human red blood cells in saline was allowed to stand for 30 minutes at room temperature with 10 times its volume of coconut water and observed for gross and microscopic evidence of hemolysis. None was found.

Serial dilutions of coconut water were made by adding 0.5 ml. of fresh coconut water to increasing amounts of distilled water. Hemolytic activity of these diluted coconut water samples was then tested by adding 0.25 ml. of a 20% suspension of human red blood cells. Samples from eight coconuts were so tested. In none of the samples did hemolysis take place until the coconut water had been diluted with three to four times its volume of distilled water.

TABLE 1.—*Summary of Chemical Analyses of Coconut Water*

Determination	Mean, mEq./Liter	Specimens Tested, No.	Deviation	Comment
Calcium	12	32	5-19	.....
Magnesium	17	22	13-25	.....
Potassium	49	32	32-80	.....
Sodium	5	32	0.5-8	.....
Chloride	63	23	42-68	.....
Phosphate	8	13	1-4	.....
Protein	180 mg./100 cc.	34	45-400 mg./100 cc.	If fluid unfiltered and filled with particles of coconut meat, protein is higher
Sulfate	5	14	1-11	.....
Glucose	2.1 gm./100 cc.	22	0.5-2.6 gm./100 cc.	Higher concentrations in younger nuts
Fructose	3.8 gm./100 cc.	22	2.5-5.9 gm./100 cc.	Higher concentrations in older nuts
Inulin	152 mg./100 cc.	6	40-325 mg./100 cc.	.....
pH	5.6	20	5.5-5.8	

CHEMICAL ANALYSIS

Electrolyte analyses have been run on a total of 41 coconuts. On some of these samples only a few analyses have been made, but a complete chemical analysis has been carried out on 20 such specimens of coconut water. The results of these determinations are presented in Table 1. Sodium, potassium, and magnesium determinations were made in the Weichselbaum-Varney flame photometer.[43] pH determinations were made on coconut water with use of the Beckman pH meter. Bacterial contamination was noted to decrease the acidity of the fluid, and it was therefore necessary to carry out pH determinations on fresh sterile samples of coconut water. Calcium determinations were done according to the method of Clarke and Collip.[12] Inorganic phosphorus was determined by the method of Fiske and Subbarow.[16] Nitrogen determinations were done by micro-Kjeldahl technique. Chloride determinations were done according to the method of Schales [33]; sulfate, by Letonoff and Reinhold's method.[25] Total reducing sugars were determined by the Shaffer, Hartman, Somogyi method.† Fructose and inulin determinations were done by the method of Rolf, Surtshin, and White.[31]

† References 34 and 38.

A temporarily confusing situation arose when during carbohydrate determinations a higher fructose level was obtained than was found for total reducing sugar in the same sample. This we found was due to the presence of inulin, a 16 molecule polymer of fructose. In the unhydrolyzed state a low reducing sugar level is noted, but when the material is hydrolyzed, 16 fructose molecules are released, resulting in increased reduction of copper sulfate. Inulin determinations were made according to the method of Young and Ruisz.[44]

The electrolyte composition of coconut water varied somewhat according to the age of the coconut from which it was drawn. In general, it has the characteristics of a hypotonic intracellular fluid (Fig. 5). The total cation or anion content averaged 81 mEq. per liter (a little over one-half that of human plasma). The average pH of coconut water was found to be 5.6. These pH determinations were consistently within the narrow limits of 5.5 to 5.8. The buffering capacity of coconut water is low because the anions are largely chloride and phosphate; only traces of bicarbonate are present. The protein content is consistently low, ranging from 40 to 450 mg. per 100 cc.

Potassium clearly forms the largest proportion of the coconut water cation, just as it does in the intracellular fluid of man. The concentrations of magnesium and calcium are also high in coconut water, whereas only traces of sodium are present.

TOXICITY STUDIES IN ANIMALS

Preliminary animal toxicity studies of intravenously administered coconut water were carried out in Bangkok, Thailand.‡ At that time we did not have access to any previous literature concerning the parental use or chemical composition of this material. Eight healthy adult mongrel dogs under intravenous pentobarbital (Nembutal) anesthesia were given 300 to 500 ml. of fresh coconut water intravenously. Temperature, pulse rate, respiration, and clinical appearance were recorded at five-minute intervals. Intravenous administration was at a very slow rate (10 drops a minute at first) in order to determine whether reactions could occur. It was soon evident that the rate could be increased, and all subsequent infusions were given at approximately 6 to 10 ml. a minute. Neither plasma nor urine showed evidence of free hemoglobin, indicating that hemolysis did not occur.[15]

More detailed animal studies have since been carried out in St. Louis with coconut water obtained from Miami. Fla.

Acute toxicity studies have been made by administering 400 ml. of fresh coconut water intravenously to five unanesthetized adult mongrel dogs at a rate of 6 to 10 ml. a minute. There were no untoward reactions noted in any of these animals receiving uncontaminated coconut water.

One animal received 400 ml. of intravenous coconut water which had been stored overnight in the cold room and was subsequently proved to be contaminated. This animal died of an overwhelming bacteremia on the second postinfusion day. Microscopic examination of the organs of the other animals receiving coconut water showed no evidence of altered cellular structure in the liver, spleen, kidney, heart, or lungs.

‡ In the laboratory of Dr. Arun Netrasiri, professor of pediatrics, Siriraj Medical School, Bangkok, Thailand.

Chronic toxicity studies were carried out by giving three adult mongrel dogs 250 to 300 ml. of coconut water intravenously twice a week for eight weeks. This fluid was given at an average rate of 6 ml. a minute and occasionally as fast as 10 to 12 ml. a minute. When the faster rate was employed, the dogs occasionally showed evidence of nausea by retching; vomiting was rare even when the fluid was given at a rate of 15 ml. a minute. These rare side-effects disappeared when the rate of injection was decreased.

No evidence of sensitivity was noted in any of these animals even after the prolonged administration of coconut water. Precipitin titers of the dogs' sera against coconut water were unchanged throughout the eight-week period. The three animals were killed at the end of eight weeks of observation. At autopsy there was no gross or microscopic evidence of damage in any of the organs examined (liver, lungs, spleen, kidney, heart, adrenals, pancreas).

TESTS FOR SENSITIVITY

One of the obvious sources of danger of giving a fluid of vegetable origin intravenously is that of allergic reaction to the foreign protein. Although the protein content of coconut water is low, even traces are potentially antigenic. Adult rabbits were used to investigate the antigenic potentialities of coconut water. Five rabbits were given 5 ml. of fresh coconut water intravenously twice weekly for nine weeks. Precipitin titers of rabbit serum against coconut water dilutions, as well as companion tubes of coconut water against serial serum dilutions, were prepared each week during the period of administration of coconut water and for three weeks thereafter. The tubes were read after incubation at room temperature for two hours. Titers were unchanged throughout the period of administration in all cases. The highest titer recorded was 1:128.

Three rabbits were given 5 ml. of coconut water intravenously twice weekly for four weeks and then received no more coconut water for five weeks. The administration of coconut water was then resumed and continued every three days for two weeks. The precipitin titers did not change, and there was no sign of a sensitivity reaction in any of these rabbits.

The intradermal injection of 0.1 ml. of coconut water into the shaved abdominal skin was carried out every week on each of the rabbits receiving coconut water intravenously. In no instance was there evidence of cutaneous sensitivity. A temporary area of erythema at the injection site disappeared by the end of 30 minutes.

PATIENT STUDY

Twenty-one patients have received a total of 26 infusions of coconut water with a low fat content. The volume of each infusion has varied from 300 to 550 ml., as shown in Table 2. Except for the first two patients, when we were fearful of immediate reaction, the rate of administration has been 5 to 6 ml. a minute. In each case we have given the material slowly (15 ggt./min.) for the first three or four minutes to be sure that the patient was not sensitive to coconut water; none were. As soon as the patient was shown to tolerate the infusion, the faster rate was employed.

All the patients under study were hospitalized, either in the Siriraj Hospital or Chulalongkorn Hospital, in Bangkok, or in the Barnes Hospital, in St Louis. None

of the patients was acutely ill at the time the coconut water was administered, and all were passing urine at normal rates. A preliminary report of the early clinical study in Bangkok previously has been made.[15]

In four cases infusions of coconut water were given on two consecutive days to the same patient. One person received three coconut-water infusions totaling 1,070 ml. over a four-day period. None of these patients showed any signs of sensitivity or other reaction to it. It is obvious that clinical experience from this small number

TABLE 2.—*Summary of Cases Receiving Coconut Water Intravenously*

Case No.	Hospital	Coconut Water, Ml.	Preinfusion Preparation*	Time Required for Infusion	Comment†
1	Siriraj	400	None	3 hr.	.....
	Siriraj	400	None	2 hr.	48 hr. after first infusion
	Siriraj	275	None	2 hr.	24 hr. after second infusion
2	Siriraj	350	None	2 hr.	Transient hives and temp. elevation
3	Siriraj	275	None	2 hr.	.....
4	Chulalongkorn	400	None	3 hr.	Local inflammation along donor site
5	Barnes	300	Autoclaved	2 hr.	.....
	Barnes	350	Autoclaved	50 min.	.....
6	Barnes	325	Autoclaved	40 min.	.....
7	Barnes	350	Autoclaved	50 min.	Temp. elevation to 39 C. sample autoclaved for two 20-min. periods
	Barnes	350	Autoclaved	60 min.	48 hr. after first infusion
8	Barnes	200	None	25 min.	.....
9	Barnes	250	None	45 min.	.....
10	Barnes	300	None	30 min.	.....
11	Barnes	275	Penicillin	35 min.	.....
12	Barnes	325	Penicillin	45 min.	.....
13	Barnes	500	Penicillin	2 hr.	.....
	Barnes	275	Penicillin	50 min.	Two days after first infusion
14	Barnes	400	Penicillin	65 min.	.....
15	Barnes	375	Autoclaved	35 min.	.....
16	Barnes	350	Autoclaved	40 min.	.....
17	Barnes	275	Autoclaved	30 min.	.....
18	Barnes	375	Autoclaved	40 min.	.....
19	Barnes	300	Autoclaved	45 min.	.....
20	Barnes	325	Penicillin	50 min.	.....
21	Barnes	450	Penicillin	90 min.	.....

* Preinfusion—autoclaving consists of treating at 20 lb. pressure for 20 min. Penicillin consists of 100,000 u. placed with coconut water during infusion.

† No reaction to infusion unless otherwise noted under "Comment."

of patients is too limited to warrant any conclusions concerning the primary sensitivity to intravenous infusion of coconut water or the possible reaction of a person to multiple infusions.

Very early in the patient study, when the rate of infusion was fast, it was noted that discomfort was felt along the course of the vein into which the coconut water was being infused. When the rate of infusion was less than 5 ml. a minute, no discomfort was noted. When larger veins were used, such as in the antecubital space, a much faster rate of infusion was tolerated without discomfort. Coconut-water infusions may be given without difficulty in the smaller veins of the forearm and hand but must be given somewhat slower to avert discomfort.

After infusion, regardless of the rate or size of vein employed, we found no evidence of thrombophlebitis or thrombosis.

Two patients demonstrated minor reactions to the administration of coconut water. One man in Bangkok (Case 2) developed generalized urticaria one hour after the infusion of 350 ml. These symptoms were easily controlled with antihistaminics, and no other signs of toxicity developed. The other reaction (Case 7) occurred in a man who inadvertently received coconut water that had been autoclaved for two 20-minute periods. The infusion was uneventful, but the temperature rose to 39 C. the evening following infusion. The temperature had returned to normal by the next morning. It is possible that some of the fat or protein constituents of coconut water are not stable to prolonged autoclaving.

The high potassium content of coconut water (49 mEq. per liter) has given us some concern in the intravenous administration of this fluid, although to date there has been no sign of potassium intoxication. We have been particularly alert for the appearance of cardiac irregularity. Several factors must be considered in this regard. The tolerance to relatively large amounts of potassium is probably due to the fact that all these patients were well hydrated, had an adequate urinary output, and were not suffering from acidosis. Under these conditions potassium intoxication would understandably be minimized.[22] The high concentration of calcium and magnesium in coconut water minimizes the neuromuscular effects of potassium, since these cations are known to have antagonistic physiologic activity in this regard.[36]

Although bacteriologic tests had proved coconut water to be sterile, several precautions were taken to avert bacterial contamination and infection. Nine infusions of fresh coconut water were given without autoclaving or the addition of any antibiotic. One of these patients (Case 4) developed a small local area of cellulitis at the site of infusion, which subsided spontaneously in three days. Ten samples of coconut water were autoclaved at 14 lb. (6 kg.) pressure for 20 minutes prior to administration. In most instances the solutions, which were crystal clear prior to autoclaving, developed a fine turbidity after heating. The only one of these solutions that caused any reaction was the previously mentioned sample (Case 7) which inadvertently was autoclaved twice. Seven infusions had 100,000 units of penicillin added to the donor bottle immediately after withdrawal of the fluid from the nut. None of these solutions elicited any reaction. The ideal method of insuring sterility must await further clinical trial.

COMMENT

Relatively little attention has been given to the chemical and physiologic properties of coconut water, compared with the mass of information available concerning the commercially important coconut meat and copra. Van Slyke,[39] in 1891, pointed out that fresh coconut water was sterile and could be used as a bacterial culture medium. Others [4] have shown that yeasts, molds, and numerous bacteria can be grown in coconut water. Recently, untreated sterile coconut water has been employed as a tissue culture medium.[6]

The first thorough chemical analysis of coconut water was made by Van Slyke, who found a total sugar content which varied between 3.56 to 4.58 gm. per 100 cc.

and noted that glucose was present in the unripe fruit, whereas sucrose was the predominent carbohydrate in fluid from the older nuts.[39] Since that time many corroborations of these findings have appeared.§

According to previous studies, the total carbohydrate content of coconut water varies between 3.0[30] and 7.09 gm. per 100 cc.[26] Our findings in the present study lie within the middle range of these extremes. There is no prior mention of the presence of inulin in coconut water. Dunsten[14] found small amounts of mannitol in it.

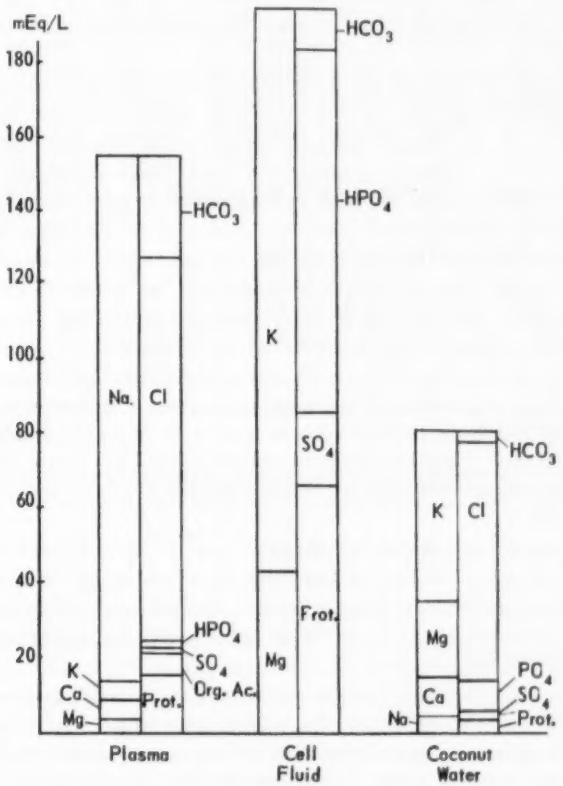


Fig. 5.—Electrolyte pattern of coconut water as compared with intracellular fluid and extracellular plasma.

The data from the present study agree generally with those of previous studies, which have largely been fragmentary.|| The electrolyte pattern of coconut water resembles that of intracellular fluid much more closely than it does that of extracellular plasma (Fig. 5). Like intracellular fluid, coconut water has potassium, magnesium, and calcium making up most of the cations, while chloride and phos-

§ References 7, 10, 13, 18, 26, 28, and 41.

|| References 28, 30, 35, and 42.

phate are the predominent anions. Previous analyses of coconut water for sodium varied considerably, but few of these reports mentioned as low concentrations of sodium as we found.

Coconut water is not a good source of vitamins, containing only nicotinic and pantothenic acids in appreciable concentrations.¶

Enzyme analyses of coconut water in the past have shown very small amounts of amylase, diastase, catalase, and peroxidase.# None are present in physiologically important concentrations.

According to Pradera, coconut-water protein is in the form of peptones or derived acid metaproteins and has no sensitizing properties in either animals or man.[28]

The fat content of coconut water increases with ripening *; unripe fruit contains as little as 0.084 gm. per 100 cc. We used only unripe fruit in this study.

When this study was begun, we were unaware that coconut water previously had been employed as a source of parenteral fluid. Some physicians in southeast Asia had the impression that the Japanese had used coconut water intravenously in Sumatra during World War II, but this could not be confirmed in Indonesia. Another physician in Thailand suggested that coconut water had been administered in Ceylon during the War by British investigators, but we have found no report of such investigation. The United States Department of Defense has no record of any such investigation of coconut water by any of its personnel.[8]

Pradera, Fernandez, and Calderin [28] in Havana, Cuba, investigated the parenteral administration of unripe coconut water in a series of pediatric patients. They administered 250 to 500 ml. of fresh coconut water to a series of 12 patients without serious reaction and found no evidence of antigenicity in guinea pigs or man. Pradera [29] has found no contraindication to its use but has been unable to continue his investigations.

Two other reports of intravenous administration of coconut water are recorded. Ciro,[11] in San Salvador, administered 20 ml. of coconut water intravenously to a number of patients without apparent untoward reaction, and Mojumbar,[27] in Calcutta, reports the administration of 100 ml. of coconut water intravenously to a 2-year-old child without reaction.

It is evident that the fluid from unripe coconuts is sterile and nonhemolytic. Its carbohydrate content is suitable for human intravenous use. The electrolyte pattern resembles that of intracellular fluid in hypotonic concentration. The most evident potential drawback would be the possible antigenicity of its protein.

All previous sensitization studies performed upon animals and man indicate that coconut water is not demonstrably antigenic. Our experience supports prior investigations in this regard. However, the number of patients tested is too small to permit a sweeping generalization. A more extensive clinical trial is now under way in Honduras,† in which it is hoped to clarify this important clinical point.

¶ References 2 and 40.

References 23 and 32.

* References 1 and 11.

† In cooperation with Dr. Edward I. Salisbury, Director of the Medical Department of the United Fruit Company, New York.

The high potassium concentration in coconut water poses the other potential hazard. Although we have noted no evidence of hyperkalism in the patients so far studied, all the subjects have had adequate renal function at the time of investigation. Whether intravenous coconut water will be tolerated by dehydrated, acidotic, or oliguric patients cannot be answered at this time. It is possible that the high concentrations of calcium and magnesium found in coconut water may increase the body tolerance to relatively high potassium levels.

SUMMARY AND CONCLUSIONS

The water from unripe coconuts has been studied as a potential source of intravenous fluid for use in areas of the world where such solutions cannot be prepared.

Fresh coconut water has been found to be a sterile pyrogen-free fluid containing between 2.5 and 5.9 gm. per 100 cc. of fructose and glucose. Its electrolyte content is largely potassium, magnesium, calcium chloride, and phosphate in hypotonic concentrations.

The protein content of coconut water is low, varying between 40 and 250 mg. per 100 cc.

In none of the samples tested has there been any in vitro or in vivo evidence of hemolysis in dogs or in man.

Rabbits and dogs tolerate large amounts of this material and show no clinical, chemical, or microscopic evidence of toxicity after acute and chronic administration. No evidence of antigenicity has been noted.

Twenty-one patients have received coconut water intravenously without evidence of serious reaction.

These preliminary data suggest that the water from unripe coconuts is a suitable source of intravenous fluid and might be utilized when other sources of pyrogen-free intravenous fluids are not available.

REFERENCES

1. Adriano, F. T., and Manahan, M.: Philippine Agriculture **20**:195, 1931.
2. Axtmayer, J. H.: Am. J. Trop. Med. **12**:323, 1932.
3. Blatter, E.: Palms of British India and Ceylon, London, Oxford University Press, 1926.
4. Blauvelt, L.: J. Lab. & Clin. Med. **24**:420, 1938.
5. Caplin, S. M., and Steward, F. C.: Science **108**:655, 1948.
6. Carey, E. M.: Philippine Agriculture **10**:55, 1921; Chem. Abstr. **16**:3980, 1922.
7. Carey, E. M.: Philippine Agriculturist **13**:229, 1928; Chem. Abstr. **19**:547, 1925.
8. Casberg, M.: Personal communication to the author.
9. Chandrasena, J. P. C.: Biochem. J. **24**:1493, 1930.
10. Chandrasena, J. P. C.: Biochem. J. **27**:3, 1933.
11. Ciro, B. J., and Dreiss, G.: Arch. Hosp. Rosalio San Salvadora **35**:66, 1943.
12. Clark, E. P., and Collip, J. B.: J. Biol. Chem. **63**:461, 1925.
13. Drummond, J. C.: Nature **155**:392, 1945.
14. Dunsten, W. R.: Trop. Agriculturist and Magazine of the Ceylon Agricultural Society **26**:277, 1906.
15. Eiseman, B.; Chongcharoensuk, S.; Jotikasathira, D., and Tantiwongse, T.: J. M. A. Thailand **35**:29, 1952.
16. Fiske, C. H., and Subbarow, Y.: J. Biol. Chem. **66**:375, 1925.

17. Galves, N.; Moreno, R., and Lava, V. G.: Philippine Agriculture **17**:163, 1928; Chem. Abstr. **1**:295, 1929.

18. Gonzalez, S., and Bienvenido, M.: Philippine Agriculture and Forrester **3**:21, 1914.

19. Jamieson, G. S.: Vegetable Fats and Oils, Ed. 2, New York, Reinhold Publishing Corporation, 1943.

20. Joachim, A. W. R., and Kandiah, S.: Agriculturist **78**:15, 1932.

21. Johns, C. O.; Finks, A. J., and Paul, M. S.: J. Biol. Chem. **37**:2062, 1919.

22. Keating, R.; Weichselbaum, T. E.; Alanis, M.; Margraf, H. W., and Elman, R.: Surg., Gynec. & Obst. **96**:323, 1953.

23. Kruyff, E. D.: Bull. du Dep. l'Agrilculture aux Indes Neerlandaises No. 4, 1906.

24. Leonard, W. A.: India Rubber Rev. **15**:11, 1915.

25. Letonoff, T. V., and Reinhold, J. G.: J. Biol. Chem. **114**:147, 1936.

26. Matthews, C. G.: Analyst. **49**:223, 1924; Chem. Abstr. **18**:2926, 1924.

27. Mojumbar, N. G.: J. India M. A. **20**:211, 1951.

28. Pradera, E. S.; Fernandez, E., and Calderin, O.: Am. J. Dis. Child. **64**:977, 1942.

29. Pradera, E.: Personal communication to the author.

30. Picado, T. C.: Bol. Ofic. san. panam. **21**:960, 1942.

31. Rolf, D.; Surtshin, A., and White, H. L.: Proc. Soc. Exper. Biol. & Med. **72**:351, 1949.

32. Roxas, M. L.: Philippine Agriculturist and Forrester **3**:33, 1914.

33. Schales, O., and Schales, S. S.: J. Biol. Chem. **140**:879, 1941.

34. Shaffer, P. A., and Hartman, A. F.: J. Biol. Chem. **45**:365, 1920-31.

35. Sherman, H. C.: Chemistry of Food and Nutrition, New York, The Macmillan Company, 1946.

36. Smith, S. G.: Am. J. Physiol. **164**:702, 1951.

37. Snodgrass, K.: Res. Inst. Stanford, 1928.

38. Somogyi, M.: J. Biol. Chem. **70**:599, 1926.

39. Van Slyke, L. L.: Am. Chem. J. **12**:130, 1891.

40. Vanderbelt, J. M.: Nature **156**:174, 1945.

41. Vista y Isles, T.: Philippine Agriculturist and Forrester **4**:109, 1915.

42. Wallace, R.: Am. J. Med. **12**:174, 1917; Chem. Abstr. **11**:2001, 1917.

43. Weichselbaum, T. E., and Varney, P. L.: Proc. Soc. Exper. Biol. & Med. **71**:570, 1949.

44. Young, M. K., and Ruisz, L. G.: Proc. Soc. Exper. Biol. & Med. **80**:771, 1952.

MALIGNANT LYMPHOMA OF THE GASTROINTESTINAL TRACT

LOUIS SPERLING, M.D.
BEVERLY HILLS, CALIF.

SURGICAL interest in gastrointestinal lymphoma obviously is limited to the solitary tumor amenable to extirpation. The prognosis in such a case is good—even better than that of gastrointestinal carcinoma treated at an early stage. This lesion of the digestive tract is not so rare as commonly thought. Singleton and Moore's collection of reports of gastrointestinal lymphosarcoma up to 1949 lists 563 cases. Its differential diagnosis is difficult. Its pathologic classification has been controversial. A brief review of the literature and observations in the series reported here confirm these impressions.

Fourteen cases of malignant lymphoma of the gastrointestinal tract have been recorded at Cedars of Lebanon Hospital, Los Angeles, between January, 1942, and January, 1952, 9 of which were in the stomach: 7 lymphosarcomas, in 1 of which there was coexistant myosarcoma; 1 reticulum cell sarcoma, and 1 Hodgkin's disease. The other five were lymphosarcomas of the ileum, of the cecum, and of the jejunum; one lymphosarcoma of the colon, classified as Hodgkin's disease, and one case of generalized lymphosarcoma of the small intestine, the colon, and the rectum (Table 1). During this same period at this institution the total number of malignant neoplasms recorded in the stomach, intestines, duodenum, and rectum was 882.

Most of these tumors originate in the gastrointestinal submucosa and infiltrate the adjacent tissues. Erosion of the mucosa may occur, followed by severe hemorrhage. The regional lymph nodes become involved early. Indeed, some investigators are of the opinion that the disease is primary in the lymph nodes and secondary in the intestine.

At the Cedars of Lebanon Hospital lymphoid tumors are classified as follows:

1. Follicular lymphoma. Alteration of the normal architecture, due to proliferation of the germinal centers, so that giant follicles occupy the cortical and medullary portions of the lymph node

2. Lymphosarcoma. Large reticulum cell type of growth or that consisting in smaller lymphoid elements

3. Hodgkin's disease. Lymphoid tumors with Reed-Sternberg cells, usually pleomorphic, but not subclassified

All three lymphoid tumors may be different manifestations of one underlying process. It has been suggested that there is a close correlation between microscopic

From the Department of Surgery and the Division of Laboratories, Cedars of Lebanon Hospital, Los Angeles.

Assistant Clinical Professor of Surgery, University of California School of Medicine at Los Angeles.

TABLE 1.—*Summary of Data in Fourteen Cases*

Patient	Admitted Date	Age, Yr.	Sex	Diagnosis	Duration of Symptoms	History	Physical Observations Abdomen
F. R., 87094	12/../43	60	F	Lymphosarcoma stomach	3 mo.	Weakness; epigastric distress, occasional vomiting, 3 wk.	Negative
L. G. K., A15022	11/../45	52	M	Lymphosarcoma stomach	6 mo.	Epigastric distress; 10 lb. wt. loss; perforated ulcer 6 mo. before	Epigastric tenderness
L. C., 61042	7/../46	41	F	Lymphosarcoma stomach	Recur. 5 yr.	Epigastric distress relieved by food and soda	Negative
J. M., 77654 (clinic)	4/../49	42	F	Lymphosarcoma stomach	18 mo.	LUQ pain; nausea; vomiting; loss appetite; 10 lb. wt. loss	Tenderness
B. F., A58538	10/../49	67	F	Lymphosarcoma stomach	4 mo.	Epigastric pain radiating to back, relieved by milk; GI series 4 mo. prior; gastric polyps	Mass upper abdomen
J. B., A54954	12/../49	47	M	Lymphosarcoma stomach	6 mo.	Epigastric distress relieved by food; tarry stools	Negative
P. K., 86062 (clinic)	5/../52	66	F	Lymphosarcoma stomach and myosarcoma	2 yr.	Vague; 12 lb. wt. loss in 2 yr.; bitter taste, mouth	Mass LUQ interpreted as spleen
A. D., 92194	6/../43	59	F	Reticulum cell ca. stomach	3 yr.	Nausea and vomiting; 40 lb. wt. loss	Mass RUQ
S. B., A47637	4/../49	70	M	Isolated Hodgkin's disease stomach	2 wk.	Nausea; vomiting; upper abdominal pain; tarry stools; gastric ulcer diagnosed 1 yr. ago elsewhere; symptoms abated on medical management	Negative
B. H., 833345	10/../47	57	M	Lymphosarcoma ileum	1 yr.	Bleeding from bowel; operation 1 yr. before for perforated Meckel's diverticulum	Negative
F. B., A70147	6/../51	72	M	Lymphosarcoma jejunum	3 mo.	Pain after meals; vomiting; 50 lb. wt. loss over 1½ yr.	Freely movable mass left side
W. O., A47262	3/../49	60	F	Gen. lymphosarcoma small and large intestine and rectum	5-6 wk.	Diarrhea followed in 3 wk. by bright red blood in stool; crampy abdominal pain; 6 lb. wt. loss	Round movable nontender mass RLQ; round tender mass left of umbilicus
M. K., 441168	8/../48	62	M	Lymphosarcoma cecum	2 mo.	RLQ discomfort; wt. loss, anorexia	Large hard mass RLQ
P. H., A72590	8/../51	67	M	Lymphosarcoma (Hodgkin's) colon	3 mo.	Wt. loss 32 lb.; anorexia; anemia; black stools	(?) mass LUQ; palp. liver

structure and life expectancy. Madding and Walters feel that prognosis in lymphoblastoma and reticulocytoma is less favorable than in the small round-cell sarcoma, possibly because of the increased sensitivity of the latter to radiation.

The feasibility of arresting the course of lymphatic disease by removal of a localized primary lesion is now fairly well established. Until recently a lymphosarcomatous tumor was viewed as a local manifestation of a systemic disease. In 1926 Desjardins stated that "a permanent cure of lymphosarcoma is unknown," while Cutler and Buschke, in 1938, indicated that treatment of lymphosarcoma should be limited to radiation therapy and that surgery was contraindicated. Since then, however, most writers believe that treatment of choice for a discrete localized

of Malignant Lymphoma of Gastrointestinal Tract

Roentgenologic Diagnosis	Operative Findings and Procedure	Node Involvement	Roentgen Therapy	Subsequent Course	Follow-Up
Ca. stomach	Bulky tumor middle third stomach; wide subtotal gastric resection	Yes	Yes	Reoperation for obstruction jejunojejunostomy 6th p. o. day	Died, generalized metastasis 3/../44 (4 mo.)
Filling defect interpreted as ca.	Mass 7.5 cm. greater curvature; subtotal ⅔ gastric resection	Yes	Yes	Uneventful convalescence	Well 5/../53 (7½ yr.)
Ulcerative ca. stomach	Mass distal ⅔ stomach; subtotal ⅔ gastric resection	Yes	Yes	Uneventful convalescence	Well 6/../52 (6 yr.)
Hypertrophic gastritis; ulcer crater lesser curvature, benign	Diffuse thickening gastric wall; large ulcer crater; 4/5 gastric resection, Billroth-I anastomosis	Yes (mult.)	Yes	Uneventful convalescence	Well 5/../50 (1 yr.)
Ulcer. ca. pyloric end stomach	Large tumor prepyloric area and greater curvature; subtotal gastric resection	No	Yes	Uneventful convalescence	Well 3/../52 (2½ yr.)
Gastric polypoid lesion, greater curvature	Large ulcer greater curvature with rolled edges; ½ gastric resection, Billroth-I anastomosis	Yes (many)	Yes	Uneventful convalescence	Died 10/../50 (10 mo.)
(?) gastritis with ulceration, lymphosarcoma, leiomyoma, splenomegaly	Tumor gastric fundus; wedge excision; biopsy liver and spleen; excision, biopsy lymph nodes	...	...	Uneventful convalescence	Well 6/../52 (1 mo.)
Ca. stomach	Large mass pyloric end stomach; no metastases; subtotal gastric resection	No	No	Acute coronary thrombosis 3d p. o. day; died	Died coronary thrombosis (3 days)
Gastric ulcer lesser curvature, probably benign	Prepyloric gastric ulcer grossly benign; subtotal gastric resection	No	No	Partial wound separation due to persistent cough; resutured	Well 5/../53; no evidence of peripheral Hodgkin's disease (4 yr.)
Dilated ileal loop	Dilated loop ileum with numerous yellowish nodules	Yes	No	Stormy convalescence; peritonitis; ileus; renal shut-down	Well 5/../53 (5½ yr.)
None	Large tumor mass jejunum with extensive involvement entire mesentery small intestine; resected approx. 135 cm. small intestine; side-to-side anastomoses	Yes	Yes	Uneventful convalescence except for transitory urinary infection	Died 5/../52 (11 mo.)
Large polypoid tumor in cecum interpreted as ca.	Ileocecal and ileoileal intussusception; multiple masses, ileum jejunum, mesentery,; resection, ileum, rt. colon; ileotransverse colostomy and enterostomy	Yes	Yes	Progressive downhill course	Died 9/../49 (6 mo.)
Large tumor, cecum	Extensive tumor with invasion aortic and regional lymph nodes; right colectomy; ileotransverse colostomy	Yes	Yes	Readmitted 9/../48 with extensive recurrence	Died 10/../48 (2 mo.)
Obstructive lesion in splenic flexure	Extensive mass in splenic flexure involving spleen, resected mass; end-to-end anastomosis, colon	Yes	Yes	Stormy convalescence; cerebral vascular thrombosis; pneumonia; wound infection	Died 11/../51 (3 mo.)

TABLE 2.—*Reported Series of Malignant Gastrointestinal Lymphoma*

Authors	Cases, No.	Survival, %	Follow-Up, Yr.
Balfour and McCann, 1930	54	21.8	5.0
Archer and Cooper, 1937	94	13.8	5.0
Taylor, 1939	152	8.5	5 to 22
Madding and Walters, 1940	41	48.5	4.0
Warren and Lulenski, 1942	14	50.0	1 to 9
Hellwig, 1947	21	57.0	5 to 20
Marshall and Meissner, 1950	32	50.0	4.5
Crile and others, 1952	19	68.0	5.0

lymphosarcoma is complete excision, with postoperative radiation therapy if doubt exists as to complete removal. A number of reported series confirm this view (Table 2).

GASTRIC LYMPHOMA

Approximately 1 to 3.2% of malignant lesions of the stomach are sarcomatous, more than half of which are lymphosarcoma. The first reported cure of gastric lymphosarcoma was that in a man who was alive and well 19 years after subtotal gastric resection, done when he was aged 9 years, for this lesion. This case was reported in 1935 by Jones and Carmody. The majority of the series listed in Table 2 involved gastric lesions. Especially encouraging are the figures cited by Marshall and Meissner from the Lahey Clinic in 1950 and those from the Cleveland Clinic reported by Crile in 1952. The former reported five-year survivals in 33% of patients who had total gastric resection for localized malignant lymphatic lesions and in 42% of those who had partial gastric resection. Crile's series of 19 cases of gastric lymphosarcoma recorded five-year survivals in 68%.

Diagnosis.—Gastric lymphosarcoma does not follow any definite diagnostic pattern. The difficulty of diagnosis is stressed in all reports.

Clinical manifestations of gastric lymphosarcoma can be as protean as those of carcinoma. Vague epigastric pain may appear first, or an ulcer-like syndrome may occur. Vomiting is unusual because of the infrequent involvement of the pylorus. There may be loss of weight and strength and other constitutional symptoms.

The most frequent positive physical sign is a palpable mass in the abdomen; other physical observations are the same as in carcinoma.

Laboratory tests are not of definite diagnostic value. Anemia may be present. Blood will appear in the stool if there is ulceration of the mucosa. Gastric analysis may or may not reveal the presence of achlorhydria.

Differential Diagnosis.—Gastric lymphosarcoma must be differentiated from hypertrophic gastritis with giant rugae, from carcinoma, and from polyposis. It is difficult to recognize, even on direct inspection at the time of operation. Only biopsy and examination of a frozen section determines the exact nature of the lesion.

Roentgenography usually fails to differentiate lymphosarcoma from carcinoma. Rafsky and his colleagues made a correct roentgenologic diagnosis in only 4 of 12 cases; McSwain and Beal, in only 1 of 8. In none of Madding and Walters' series of cases was the roentgenologic diagnosis correct. Taylor considered two or more filling defects and giant rugal folds as indicative of lymphosarcoma. Roentgenologic study, although evidently not so accurately diagnostic in this disease as in others of the gastrointestinal tract, does reveal a lesion warranting exploration.

Gastroscopy may be helpful. Schindler believes it superior to all other diagnostic procedures; he cites a case in which gross pathologic tissue could not be found at the time of operation, but biopsy at the site of the lesion observed gastroscopically revealed lymphosarcoma. The characteristic appearance, as described by him, is that of stiff folds with polyp-like nodules protruding from their edges. Generalized stiffness of the mucosa with superimposed polyp-like nodules suggests diffuse lymphosarcoma. Blomquist, cited by Schindler, believes that the nodules in lymphosarcoma have a peculiarly transparent aspect, and he was able to make a correct diagnosis solely on this gastroscopic picture. All observers describe marked hypertrophy of the rugal folds with polypoid, whitish nodules resistant to air inflation.

Report of Cases of Gastric Lymphosarcoma or Reticulum Cell Sarcoma.—Six of the nine patients with malignant lesions of the stomach in our series are still alive, their periods of postoperative survival being seven and a half, six, four, two and a half, and one year, and a recent case in which one month has elapsed since operation. With exception of the patient with discrete localized Hodgkin's disease, all were treated postoperatively by irradiation. Although conclusions may not be drawn from so small a series and with but limited follow-up, the favorable results are encouraging.

Three patients with malignant gastric lesions have died. One 59-year-old woman (Case 8) died of cardiac complications three days postoperatively. A large, localized, reticulum cell sarcoma of the stomach, without extension or metastasis, had been resected. Another woman (Case 1), aged 60, died approximately four months after operation. She had received irradiation following resection of a large fungating lymphosarcoma of the stomach without evidence of metastasis at that time. Generalized abdominal and thoracic metastases were found at postmortem examination. The third death was that of a man aged 47 (Case 6), approximately 10 months after resection of a large lymphosarcoma of the greater curvature of the stomach. Evidence of metastases was not found in numerous lymph nodes removed from the gastrocolic omentum at the time of surgery. He received roentgen therapy. A large mass in the epigastrium was first noted nine months after the operation. Radiation therapy again was administered, but the patient died within a month.

The patient with a seven and a half year cure was a man aged 52 (Case 2). He had epigastric distress for six months, unrelieved by ulcer regimen. Approximately six months prior to admission he had undergone surgery elsewhere for closure of a perforated ulcer. He lost 10 lb. (4.5 kg.) in weight. Roentgenologic examination indicated a filling defect in the stomach, interpreted as carcinoma. When he entered Cedars of Lebanon Hospital, on Nov. 13, 1945, tenderness in the epigastrium was the only physical sign, there being no palpable masses.

On Nov. 15, he was operated on. Numerous adhesions from the previous surgical procedure; a mass occupying the greater curvature of the stomach, about 7.5 cm. in diameter, and numerous hard glands in the gastrohepatic omentum were observed. Biopsy of one of the glands failed to disclose evidence of tumor. A subtotal gastric resection was done, about two-thirds of the stomach being removed. The microscopic diagnosis was lymphosarcoma of the omentum and mesenteric lymph nodes, with considerable involvement. Convalescence was normal, and the patient was discharged on the 12th postoperative day. Irradiation to the abdomen was administered. The patient was perfectly well in May, 1953, almost seven and a half years after removal of the lymphosarcoma. Recently he had a hemorrhoidectomy.

HODGKIN'S DISEASE OF THE STOMACH

Invasion of the alimentary tract by Hodgkin's disease is rare, usually occurring with generalized visceral involvement. A solitary discrete gastric lesion is exceedingly unusual. Schlagenhaufer, in 1913, was the first to report such a case. Hayden and Apfelbach reviewed 26 cases of gastrointestinal Hodgkin's disease and found only 3 in which it was limited to the stomach. It should be kept in mind that the disease may exist in other tissues although gross evidence of such may not be apparent. Avent reported a case of Hodgkin's disease apparently isolated to the stomach but in which multiple microscopic lesions in the liver, spleen, and bone marrow were found at autopsy. Singer made a plea for radical surgical treatment of isolated gastric Hodgkin's disease. His review of the literature prior to 1932 revealed reports of only six surgically managed cases, including those of Steindl; all were reported as surgical survivals. Twelve additional two-to eight-year survivals were reported from 1935 to 1946. According to Atlee in December, 1951, only 32 cases of gastric Hodgkin's disease had been reported as of that date.

The clinical manifestations of Hodgkin's disease, like those of true lymphosarcoma, may be indistinguishable from symptoms of gastric ulcer, carcinoma, or other neoplasm. In the presence of an isolated gastric lesion there may not be the fever,

Fig. 1 (Case 9).—Roentgenogram demonstrating gastric ulcer with crater situated on lesser curvature.

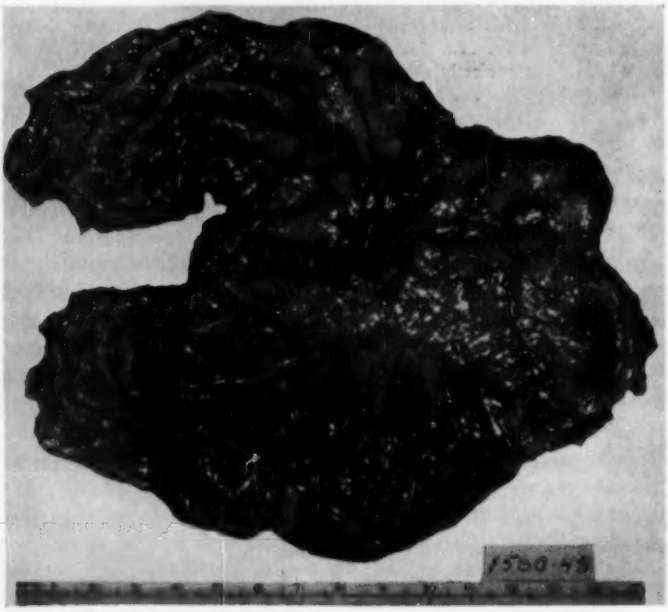


Fig. 2 (Case 9).—Hodgkin's disease with ulcer, lesser curvature of stomach.

adenopathy, or hematologic observations suggestive of the disease in general. Gastroscopy does not permit a definite diagnosis of Hodgkin's disease of the stomach, according to a number of investigators and as observed in the case of this type in the present series. Roentgenography demonstrates the presence of a lesion but may not point specifically to Hodgkin's disease. In six cases reported by Kirtlin the roentgenologic diagnosis had been carcinoma in five and obstructive duodenal ulcer in the other. In another case reported by Brown and McHardy, Hodgkin's disease was suggested by Teitelbaum on the roentgenographic basis of sluggish peristalsis and the extent of the defect, although a palpable mass was not found.

Survival of patients with isolated gastrointestinal lesions of Hodgkin's disease treated by radical resection—usually on the basis of a clinical diagnosis of carcinoma —is being reported increasingly in the literature. Thus it would seem that radical

Fig. 3 (Case 9).—Hodgkin's disease with ulcer, lesser curvature of stomach. Cut surface showing penetrating ulcer.

resection for localized lesions of Hodgkin's disease is a wise choice of therapy, and that in cases without distal or peripheral manifestations of the disease the prognosis is good.

Report of a Case of Gastric Hodgkin's Disease.—A 70-year-old white man (Case 9) had been treated medically for gastric ulcer diagnosed roentgenographically; symptoms had abated. He was first seen on March 17, 1949, a year after discovery of the ulcer, at which time he complained of nausea, vomiting, upper abdominal pain, and tarry stools of two weeks' duration. Roentgenologic examination ~~of~~ the upper gastrointestinal tract demonstrated an ulcer 2.5 by 1.5 cm. A second series of roentgenograms, made after his admission to Cedars of Lebanon Hospital, were reported as "gastric ulcer crater on the lesser curvature wall at the level of the gastric angle. The appearance of the ulcer suggests a benign lesion, but it should be emphasized that no reliable criteria are present to distinguish it from a malignant growth. Comparison with a previous gastrointestinal examination three weeks ago shows that the ulcer crater has slightly decreased in size" (Fig. 1). In view of the questionable improvement roentgenographically, gastroscopy was done; at this time the impression of a probable malignant neoplasm was recorded.

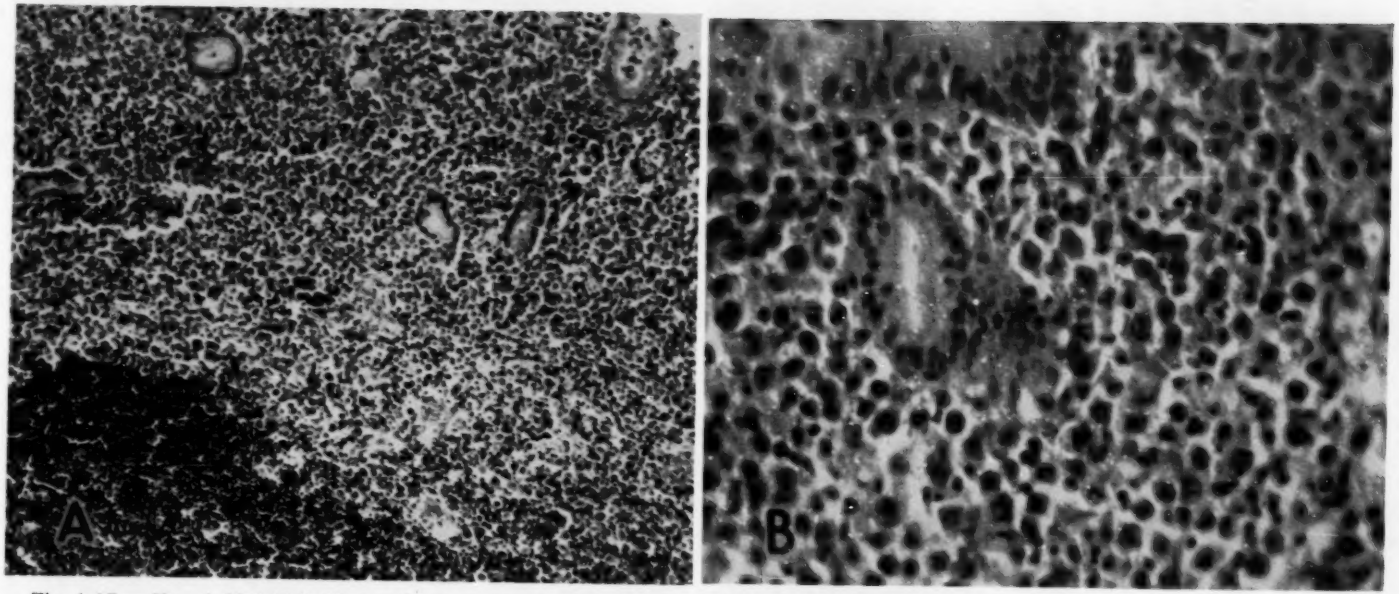


Fig. 4 (Case 9).—*A*, Hodgkin's disease with ulcer, stomach; polycellular infiltrate involving gastric mucosa (hematoxylin and eosin; × 110; *B*, Hodgkin's disease with ulcer, stomach; characteristic Reed-Sternberg cells (hematoxylin and eosin; × 300).

On April 12, 1949, a subtotal gastric resection with a retrocolic Hofmeister gastrojejunostomy was carried out. The liver and spleen were normal; enlarged lymph nodes were not found. There was a 4 by 5 cm. indurated area in the lesser curvature; the pathologist's impression on gross inspection was simple gastric ulcer without gross evidence of malignant growth (Figs. 2 and 3). However, the microscopic description (Fig. 4) stated: "The ulcer wall shows a polycellular mass consisting of mature lymphocytes, eosinophiles, plasma cells, and atypical reticulum cells of the Reed-Sternberg type. There is lymphomatous transformation involving the mucosa and submucosa and muscularis surrounding the ulcer crater. Diagnosis: Hodgkin's disease, stomach." The patient's convalescence was complicated by a persistant cough, resulting in partial wound separation which was resutured. He has done well since, is eating a full diet, and has gained weight. Radiation therapy was not given. As of February, 1954, almost five years after the operation, the patient presents no evidence of peripheral manifestations of Hodgkin's disease.

LYMPHOSARCOMA OF SMALL INTESTINE

The small intestine may be the site of lymphosarcoma. Multiple lesions may be present, as in the case to be reported. Spellberg and Zivin found the incidence of carcinoma of the small intestine to be four times that of lymphosarcoma.

The symptoms vary with the degree of obstruction and, at first, are similar to those of other obstructions to the small intestine. There may be low-grade fever and gross hemorrhage; a mass may be palpable. Roentgenograms may not distinguish lymphosarcoma from other causes of obstruction. A constant dilated loop may be seen on a plain roentgenogram.

The lower part of the ileum is involved most frequently, probably because of the increased lymphatic tissue in that region, but lymphosarcoma may occur at all points, from duodenum to terminal ileum. The lesion may be diffuse, nodular, sessile, or polypoid. Neoplasia in the submucosal lymphatics may extend through the muscularis and involve the serosa, with subsequent formation of adhesions and intestinal obstruction. The so-called garden-hose type of change, with diffuse thickening, is commoner than the "napkin ring" type.

Prognosis usually is unfavorable in lymphosarcoma of the small intestine. In 150 cases collected by Marcuse and Stout, only 20 five-year cures were recorded. They were unable to determine any correlation between the clinical and pathologic aspects and the final outcome. Some patients with advanced lesions recovered, while others with early lesions suffered rapid progression of the disease despite radical therapy. The presence of involved nodes did not always preclude a successful outcome; in one such case, in which radiation therapy was employed, an eight-year survival was recorded. Faulkner and his colleagues recently reviewed 33 cases of lymphosarcoma of the small intestine recorded at the Mayo Clinic. Of 14 patients surviving operation, only 3 lived five or more years. They are strongly of the opinion that roentgenologic therapy should follow adequate excision in every instance.

Report of Cases of Lymphosarcoma of Small Intestine.—A man, aged 57 (Case 10), had undergone exploratory operation on Oct. 23, 1947, at Cedars of Lebanon Hospital, the preoperative impression being perforated appendix with peritonitis. A perforation of the ileum, due to rupture of a Meckel diverticulum, at a point approximately 90 cm. from the ileocecal valve, was found and closed. The patient recovered and left the hospital on Nov. 5.

One year later, Nov. 15, 1948, he was readmitted with the complaint of profuse rectal bleeding for several days. The hemoglobin content was 8.5 gm. per 100 cc.; the red blood cell count, 3,240,000. Roentgenologic study of the esophagus, the stomach, and the duodenum was negative, but persistant localized dilation of a loop in the upper part of the ileum was noted. The preoperative diagnosis was dilated ileal loop, possibly containing ectopic gastric mucosa. The dilation was found to be at the site of the previous repair. The intestinal wall was thickened

and its serosal surface and the mesentery were studded with numerous yellowish nodules; there was a localized ovoid elevation, 1 by 6 cm., near the antimesenteric border. Resection and anastomosis was carried out. The pathologic diagnosis was lymphosarcoma of the ileum.

The patient's convalescence was complicated by peritonitis, paralytic ileus, and temporary renal shutdown. He made a slow recovery and finally was allowed to go home. During the next five and a half years, until May 1953, he has remained well.

Another patient with lymphosarcoma of the small intestine was a man aged 72 (Case 11) who for three months had pain after meals and vomiting and over a period of a year and a half and lost 50 lb. (23 kg.) in weight. A freely movable mass was palpated in the left side of the abdomen. He was admitted to Cedars of Lebanon Hospital on June 12, 1951. On June 14 at operation there was a large tumor in the jejunum with extensive involvement of the entire mesentery of the small intestine and very large glands. Approximately 135 cm. of small intestine was resected; a side-to-side anastomosis was done. Not all of the glands were removed. The liver seemed not to be involved. The pathologic diagnosis was lymphosarcoma of the jejunum. With exception of transitory urinary retention, the patient's convalescence was uneventful, and he was discharged on June 27, 1951. He remained well until December, 1951, when abdominal masses became palpable. Roentgenologic therapy was administered, but the patient died in May, 1952, less than a year after the operation.

LYMPHOID TUMORS OF THE COLON AND RECTUM

Malignant Tumors.—Malignant lymphoma occurs oftener in the colon than in the small intestine. McSwain and his co-workers reported two cases of lymphosarcoma of the appendix, and seven of the large intestine; in two of the latter the cecum, appendix, and terminal ileum were involved; in 1 the transverse colon, and in another the sigmoid; three were located in the rectum.

Symptoms vary according to the location of the tumor and consist in diarrhea, distention, abdominal pain, and loss of weight. Vomiting rarely occurs, as usually is the case in obstruction of the large intestine. Proctoscopic examination in rectal lymphosarcoma may reveal polyps with broad pedicles. Winkelstein, Asher, and Levy described the sigmoidoscopic appearance of lymphosarcoma of the colon as having a diffuse "hill and valley" appearance. These writers state that the appearance is so characteristic that even without biopsy one can venture the diagnosis of lymphosarcoma by sigmoidoscopy alone. They have observed four patients in whom this lesion was diagnosed correctly by sigmoidoscopy. Occasionally the rectal or sigmoid lesions may appear as a polypoid growth or even a firm ulcerated mass, and biopsy is required to establish the diagnosis.

The prognosis of lymphosarcoma of the colon in all reported cases is uniformly bad. If complete early excision can be done, the outlook, no doubt, would be better than reported. Harris and Goldman reported a case of lymphosarcoma of the rectum treated by local excision fulguration with a five-year cure. In all cases of malignant lymphoma radical excision, even abdominal perineal resection, adequate x-ray therapy should be administered postoperatively.

All three of the patients in this series (Cases 12, 13, and 14) died within a few months following operation.

Benign Tumors.—Benign lymphoma of the rectum is not as rare as has been previously reported. It is interesting to note that Gabriel reported that at St. Mark's Hospital, in London, only 40 cases of lymphoma of the rectum had been recorded up to the date of publication of his book, in 1948; the youngest patient was aged 6½ years; the oldest, 63. Hayes and his co-workers collected 20 cases of benign lymphoma of the rectum from the literature. Helwig and Hansen collected 70 cases of lymphoid polypoid rectal tumors and studied the records of 395 patients with

generalized lymphoma. Of those with benign lymphoma, in 40 the lesions were solitary, in 25 they were multiple, and in 5 the number was not recorded. Predilection for any particular site in the rectum was not apparent, and gross descriptions of the polyps varied widely. Malignant lymphoma involving the rectum was rare in their series, only 17 of the 395 cases were so recorded.

SUMMARY

It is apparent that an increasing number of patients with isolated involvement of the gastrointestinal tract by malignant lymphoma have survived radical resection —usually with a mistaken clinical diagnosis of carcinoma.

A report is presented of 14 cases of malignant lymphoid tumor of the gastrointestinal tract. Nine were of the stomach; the remainder involved the small bowel and the colon. Six of the nine patients with malignant lymphoma of the stomach are still alive, their periods of postoperative survival being seven and a half, six, four, two and a half, and one year, and in the most recent case one month. The patients with malignant lymphoma of the small intestine and the colon, with one exception, have all died; the patient who has survived has a five and a half year record to date.

Malignant lymphoma of the stomach seems to have a better prognosis following surgical excision than similar lesions elsewhere in the gastrointestinal tract. Localized involvement should probably be treated by radical resection and followed by a course of deep roentgen therapy, although two of our patients survived four and five and one-half years without such therapy.

405 N. Bedford Dr.

BIBLIOGRAPHY

Archer, V. W., and Cooper, G., Jr.: Lymphosarcoma of the Stomach: Diagnosis and Treatment, Am. J. Roentgenol. **42**:332, 1939.

Atlee, J. L., Jr.; Rowan, P. J., and Ziegler, E. E.: Hodgkin's Disease of the Stomach with Free Perforation and Apparent Surgical Cure, Ann. Surg. **134**:1052, 1951.

Avent, C. H.: Primary Isolated Lymphogranulomatosis (Hodgkin's Disease) of the Stomach, Arch. Surg. **39**:423, 1939.

Balfour, D. C., and McCann, J. C.: Sarcoma of the Stomach, Surg., Gynec., & Obst. **5**:948, 1930.

Borden, D. L., and Taylor, F. D.: Primary Lymphosarcoma of the Small Intestine, Mil. Surgeon **92**:255, 1943.

Browne, D. C., and McHardy, E.: Isolated Hodgkin's Disease of the Stomach, Gastroenterology **6**:596, 1946.

Carache, J.: Primary Lymphosarcoma of the Intestine in a Boy Aged Seven: Follow-up of Nine Years, Am. J. Surg. **59**:601, 1943.

Crile, G., Jr.; Hazard, J. D., and Allen, K. L.: Primary Lymphosarcoma of the Stomach, Ann. Surg. **135**:39, 1952.

Cutler, G. D., and Buschke, F.: Cancer, Its Diagnosis and Treatment, Philadelphia, W. B. Saunders Company, 1938.

Desjardins, A. U.: Radiotherapy for Hodgkin's Disease and Lymphosarcoma, J. A. M. A. **99**:1231, 1932.

Faulkner, J. W., and Dockerty, M. B.: Lymphosarcoma of the Small Intestine, Surg., Gynec. & Obst. **95**:76, 1952.

Gabriel, W. B.: Principles and Practice of Rectal Surgery, Springfield, Ill., Charles C Thomas, Publisher, 1948, p. 483.

Harris, F. I., and Feigen, G. M.: Lymphosarcoma of the Rectum: Five Year Cure Following Local Removal, Am. J. Surg. **72**:277, 1946.

Hayden, H. C., and Apfelbach, C. W.: Gastro-Intestinal Lymphogranulomatosis, Arch. Path. & Lab. Med. **4**:743, 1927.

Hayes, H. T.; Burr, H. B., and Pruit, L. T.: Lymphoid Tumors of the Colon and Rectum, Surgery **7**:540, 1940.

Hellwig, C. A.: Malignant Lymphoma, Surg., Gynec. & Obst. **84**:950, 1947.

Helwig, E. B., and Hansen, J.: Lymphoid Polyps (Benign Lymphoma) and Malignant Lymphoma of the Rectum and Anus, Surg., Gynec. & Obst. **92**:233, 1951.

Jones, T. E., and Carmody, M. G.: Lymphosarcoma of the Stomach: Report of a Case with a 19 Year Surgical Cure, Ann. Surg. **101**:1136, 1935.

Kirklin, B. R.: Relative Merits of Gastroscopic and Roentgenologic Examination, Radiology **29**:492, 1937.

McSwain, B., and Beal, J. M.: Lymphosarcoma of the Gastro-Intestinal Tract: Report of 20 Cases, Ann. Surg. **119**:108, 1944.

Madding, G. F.: Hodgkin's Disease of the Stomach: Report of 6 Cases, Proc. Staff Meet, Mayo Clin. **13**:618, 1938.

——and Walters, W.: Lymphosarcoma of the Stomach, Arch. Surg. **40**:120, 1940.

Marcuse, P. M., and Stout, A. P.: Primary Lymphosarcoma of the Small Intestine: Analysis of 13 Cases and Review of the Literature, Cancer **3**:459, 1950.

Marshall, S., and Meissner, W. A.: Sarcoma of the Stomach, Ann. Surg. **131**:824, 1950.

Rafsky, H. A.; Katz, H., and Krieger, C. I.: Varied Clinical Manifestations of Lymphosarcoma of the Stomach, Gastroenterology **3**:297, 1944.

Schindler, R.: Gastroscopy, Chicago, University of Chicago Press, 1937, p. 276.
Gastroscopy: The Endoscopic Study of Gastric Pathology, Ed. 2, Chicago, University of Chicago Press, 1950.

Schlagenhaufer, E.: Über Granulomatosis des Magendarmtrackts, Zentralbl. allg. Path. **24**:965, 1913.

Singer, H. A.: Primary Isolated Lymphogranulomatosis of the Stomach, Arch. Surg. **22**:1001, 1931.

Singleton, A. O., Jr., and Moore, R. M.: Lymphosarcoma of the Gastro-Intestinal Tract, Texas Rep. Biol. & Med. **7**:33, 1949.

Spellbreg, M. A., and Zivin, S.: Lymphosarcoma of the Gastro-Intestinal Tract: Report of 21 Cases, Arch. Int. Med. **83**:135, 1949.

Steindl, H.: Über einen Fall von Lymphogranulomatose des Magens, Arch. klin. Chir. **130**:110, 1924.

Taylor, E .S.: Primary Lymphosarcoma of the Stomach, Ann. Surg. **110**:200, 1939.

Warren, S., and Lulenski, C. R.: Primary Solitary Lymphoid Tumors of the Gastro-Intestinal Tract, Ann. Surg. **115**:1, 1942.

Winkelstein, A., and Levy, M. H.: Lymphosarcoma of the Intestines, 15 Cases: Characteristic Sigmoidoscopic Picture, Gastroenterology **1**:1093, 1943.

USE OF POLYVINYL SPONGE IN REPAIR OF EXPERIMENTALLY PRODUCED DEFECTS IN THE ABDOMINAL WALL

THEO L. SCHOFIELD, M.B., F.R.C.S.
GEORGE A. HALLENBECK, M.D.
JOHN H. GRINDLAY, M.D.
AND
EDWARD J. BALDES, Ph.D.
ROCHESTER, MINN.

FOR THE repair of large hernias it is often found useful to use some foreign material to reinforce or replace the damaged tissues. Many substances have been advocated—metal plates and sutures,[1] wire meshes[2] and filigrees,[3] bone plaques, skin[4] and fascial implants.[5] Many have been useful; some have been discarded soon after their introduction. This paper describes the investigation of a new material—polyvinyl formal sponge (Ivalon).*

THE MATERIAL

Polyvinyl (Ivalon) sponge is a polymer of polyvinyl alcohol with formaldehyde and is made commercially by foaming the substance during polymerization. Its possibilities in surgical techniques were first described by Grindlay and Clagett[6] and Grindlay and Waugh[7] who considered its use as a prosthesis following pneumonectomy and as a means of strengthening the wall of an abdominal aortic aneurysm. Unlike most other plastic materials being used in surgery, for example, polyethylene, nylon, Cellophane, and acrylic resin, polyvinyl sponge is wettable yet inert. When it is introduced into the body, the tissue juices enter the interstices of the sponge. As described by Schilling, Favata, and Radakovich,[8] there is no foreign body reaction in or about the sponge. Fibroblasts invade it until the mesh is completely filled. Such a substance which permits the formation of healthy fibrous tissue and at the same time maintains a framework until this has consolidated seems ideal for the purpose intended.

Tantalum and stainless-steel mesh are perhaps the most frequently used materials at the moment. Their function is to control the hernia and to allow fibrous tissue to grow through the mesh. After about 12 months or more the mesh usually fragments and the strength of the repair depends on the scar tissue alone. The high cost of tantalum and the relative difficulty of handling wire gauze are small but important disadvantages in their general use. Polyvinyl sponge has neither of these drawbacks—it is cheap and very easy to manipulate.

Fellow in Surgical Research, Mayo Foundation (Dr. Schofield).

The Mayo Foundation is a part of the Graduate School of the University of Minnesota.

From the Section of Surgery (Dr. Hallenbeck); the Section of Surgical Research (Dr. Grindlay), and the Section of Biophysics and Biophysical Research, Mayo Clinic (Dr. Baldes).

* Ivano, Inc., supplied the polyvinyl sponge.

Cumberland [9] has enumerated certain desirable qualities for a foreign body to be used for repair of a hernia: 1. It should be relatively inert biologically and chemically. 2. It must be easily sterilized. 3. It should be durable and provide a supporting framework for a sufficiently long time to allow a firm and stable fibrous tissue matrix to provide permanent cure of the hernia. 4. It should be relatively elastic so that it responds to deforming forces, for example, muscle contractions, coughing, sneezing, without tearing of its attachments to the patient's tissues. 5. It should be smooth so as not to injure viscera or vessels. 6. It should be radiotranslucent. 7. It should be readily available and cheap.

Polyvinyl sponge has been shown to be inert; it can be sterilized by boiling. It is smooth and elastic, radiotranslucent, readily obtainable, and cheap. The first part of the present study has been carried out on dogs to test its suitability for use in the repair of hernias. The second part of the study describes experiments on rabbits to test the tensile strength of defects in muscle repaired with polyvinyl sponge.

REPAIR OF DEFECTS IN THE ABDOMINAL WALL

Methods.—The aim was to create a defect in the peritoneal and musculofascial layers of the abdominal wall of large mongrel dogs, repairing some with the polyvinyl sponge at the time of the operation, leaving others in the hope that a hernia would persist and permit later repair with the same material.

With the animal under ether anesthesia and with aseptic conditions, through a midline incision the whole width of rectus muscle on both sides was excised together with its sheath and the peritoneum over a length of 8 cm. centered on the umbilicus. Laterally the oblique and transverse muscles were trimmed back a little so that the individual muscle layers could be easily identified. The resulting defect was approximately 8 cm. long and 10 cm. wide. The omentum was placed over the bowel and loosely stitched to the cut edge of the peritoneum and transverse abdominal muscle with use of fine chromic absorbable surgical (gut) sutures.

In seven dogs subcutaneous tissue and skin alone were closed over the defect.

In seven dogs the muscular defect was closed with a single layer of polyvinyl sponge 3 mm. thick, sutured with fine 000 interrupted cotton to the edge of both internal and external oblique muscles laterally and to the anterior rectus sheath at the upper and lower limits of the gap. There was an overlap of about 0.5 cm., the sponge being fixed deep to the anterior rectus sheath and external oblique aponeurosis.

In six dogs two layers of sponge were used—the deep layer sutured to internal oblique and posterior rectus sheath, the superficial layer to external oblique and anterior rectus sheath.

It was found that if the sponge was sutured in place too loosely the resulting abdominal wall appeared lax. On the other hand, in one instance in which a double layer of sponge was purposely sutured in place under considerable tension, the stitches pulled out along one edge of the sponge and the repair failed. From this one experiment it would appear that the sheet of sponge used should be large enough that after it has been sutured in place it will be under moderate but not great tension.

In an additional five dogs the defect was repaired with tantalum gauze (0.003 in. diameter wire, 50 by 50 mesh) sutured as in the single layer of sponge, but size 000 tantalum wire being used.

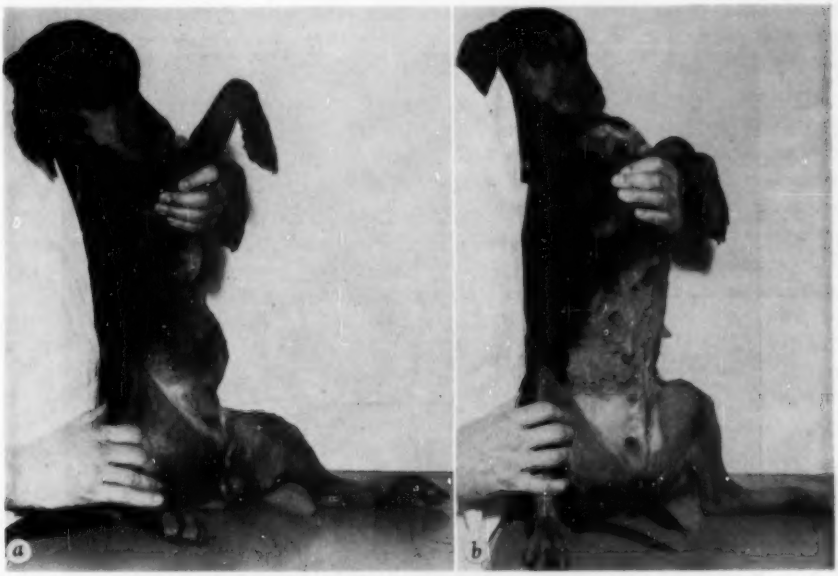


Fig. 1.—(*a*) Dog, 12 days after excision of a portion of the abdominal wall, showing ventral hernia. (*b*) Same dog, 84 days postoperatively, showing spontaneous correction of the defect.

Fig. 2.—Dog, 12 days after experimentally produced defect in the abdominal wall had been immediately repaired with one layer of polyvinyl sponge. No evidence of hernia.

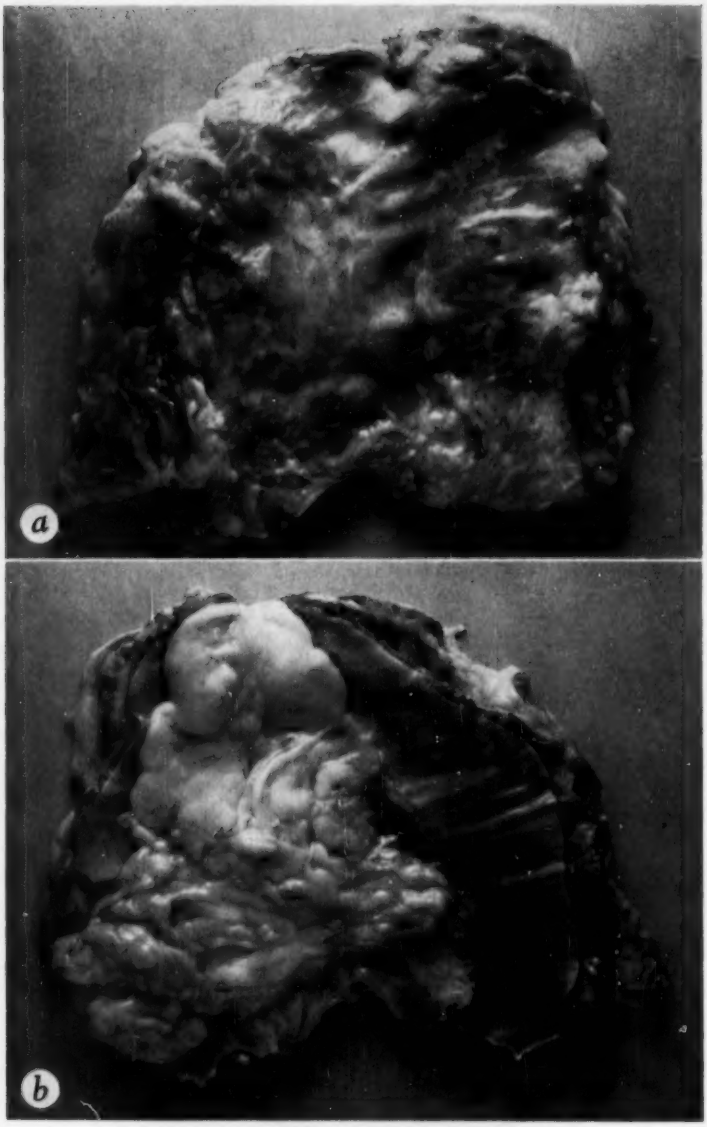
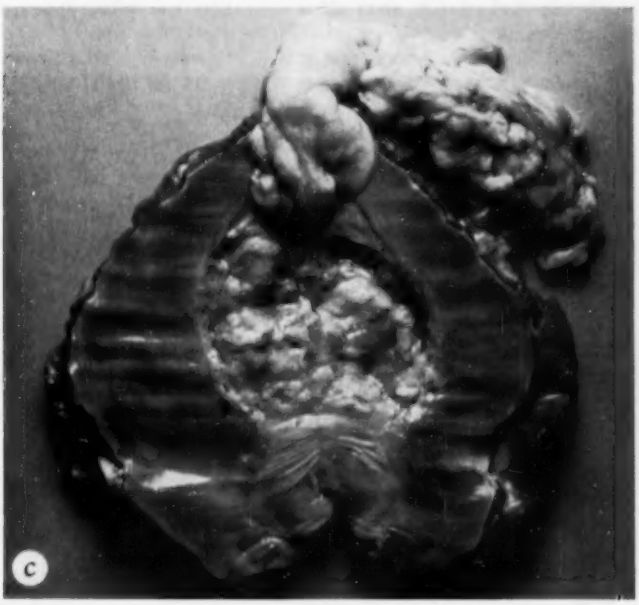


Fig. 3.—Excised segment of abdominal wall containing implanted polyvinyl sponge: (*a*) superficial surface showing facial-like sheet of fibrous tissue which covers the sponge; (*b*) deep surface showing omentum which was sutured to the edges of the defect; (*c*) deep surface, omentum easily stripped from surface of sponge.

In all animals in which a prosthesis was inserted, 1,000,000 units of crystalline penicillin in solution was sprayed over the prosthetic material before the skin was closed, and 30,000 units of procaine penicillin was given intramuscularly on the first two postoperative days.

Results.—Animals with No Prosthesis: After operation large ventral hernias developed in the seven dogs of this group. These hernias persisted for about four to six weeks. Viscera could easily be palpated beneath the skin. To our surprise the hernias then began to get progressively smaller and by 10 to 12 weeks all had undergone spontaneous cure (Fig. 1). Similar observations were reported by Koontz [10] in 1926.



Exploration was performed on two of the seven dogs 16 weeks after operation. Dense fibrous tissue filled the gap in the abdominal wall. It appeared to arise from the deep fascia over the external oblique and rectus muscles. The scarred area appeared smaller than the defect made at the original operation. There were no adhesions to the deep surface except where the omentum had been sutured to the edge of the defect.

Single Layer of Sponge: In 6 of the 7 dogs the wound healed without sepsis. In one animal a small abscess formed which was allowed to discharge spontaneously, after which the wound healed completely. In no instance did a hernia develop (Fig. 2). In one instance in which the sponge had been sutured with insufficient tension, there was a slight bulge, but at no time was there any gross herniation such as occurred in the control series. The edge of the defect could be easily palpated at first, but as fibrosis progressed it became increasingly difficult to distinguish between the edge of muscle and the sponge.

Exploration through the original incision was performed in four cases 10 weeks after operation. In the midline the subcutaneous tissue tended to be adherent to the surface of the sponge which was covered by a glistening layer of areolar tissue, continuous with the deep fascia of external oblique and anterior rectus sheath. This layer was incised to reveal the underlying sponge to which it was firmly adherent. The edges of the sponge had become blended with the edges of the defect. On the deep surface the omentum was adherent, but no other adhesions were present.

Biopsies of the sponge were taken. In one of the four dogs the sponge was incised throughout its length in the midline and resutured with 000 cotton.

All the dogs in this group were killed six to eight months after the original operation. In none was there any evidence of a hernia at any time after operation. The dog with the slight bulge soon after operation had what appeared to be a normal abdominal wall.

Fig. 4.—Photomicrograph (× 30) of junction between polyvinyl sponge and abdominal wall. Note that the interstices of sponge are completely filled with fibrous tissue which becomes continuous with the scar in the muscle.

All, except the one which had become infected, showed the same features when dissected. Healed incisional scars in skin and subcutaneous layers were adherent to the fibrous tissue covering the sponge, but elsewhere the subcutaneous tissues could be easily separated from the deep fascia and fibrous tissue covering the sponge. There was a dense sheet of scar tissue stretching from the edge of the defect across the surface of the sponge and covering it completely (Fig. 3 *a*). This layer was firmly adherent to the underlying sponge and could be separated from it only by sharp dissection. On the deep surface the omentum was firmly attached to the edge of the defect where it had been sutured (Fig. 3 *b*) but over the sponge it was not so adherent and could be stripped off (Fig. 3 *c*). There were no other adhesions in the abdominal cavity.

The sponge was pliable, and microscopic examination showed that the interstices were filled with fibrous tissue, continuous at the edges with the scar in the muscle (Fig. 4).

In the four dogs in which biopsy specimens had been taken, there was no macroscopic evidence of such a procedure. There had been complete healing of the suture line in the sponge which had been incised throughout its length.

In the dog in which there had been sepsis in the wound, the findings were different. There was thickening in the line of incision, and the subcutaneous tissues were unusually adherent to the deep fascia. A small locule of pus was found in the subcutaneous layers. The repair appeared normal from the external surface, but on the peritoneal aspect there were many firm adhesions of both omentum and intestine to the area of the sponge (Fig. 5 *a*). There was no evidence of any previous generalized peritonitis. When the defect was incised, it was found to have been repaired by a thick-walled abscess in the cavity of which the polyvinyl sponge lay completely free (Fig. 5 *b*). Microscopic examination showed that the sponge was filled with purulent debris only.

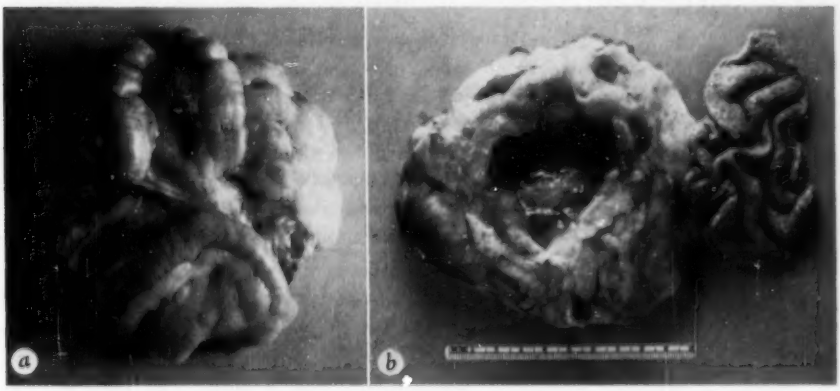


Fig. 5.—Excised segment of infected abdominal wall containing implanted polyvinyl sponge: (*a*) deep surface showing omentum and bowel more adherent to sponge than was the case in the absence of infection; (*b*) abscess opened; sponge free inside (the scale is metric).

Double Layer of Sponge: The results in these six dogs were similar to those with a single layer of sponge. Scar tissue had amalgamated the layers which had been invaded throughout to form one single thickness.

In one dog there had been a subcutaneous effusion seven days after operation and 150 ml. of blood-stained fluid was aspirated. After this, healing was uneventful. At necropsy this dog differed from the rest only in that the dense fibrous tissue layer which stretched from the edges of the defect over the sponge could be separated relatively easily from a thinner fibrous layer firmly adherent to the sponge. At the edges the sponges were firmly incorporated in the muscle scar.

Tantalum Gauze Insert: No hernia was seen in this group. In four of the five dogs subcutaneous collections of fluid developed after the operation, and in three it was necessary to aspirate the fluid on more than one occasion.

When the dogs were killed 16 weeks after operation, the wire gauze was found firmly imbedded in fibrous tissue which had contracted to cause corrugation of the mesh. In one dog fragmentation of the mesh had already occurred, but the scar tissue adequately prevented herniation.

Comment.—The dog is not an ideal animal for testing the suitability of a prosthesis for the repair of an experimentally produced ventral hernia because such hernias disappear spontaneously over a period of 10 to 12 weeks. Polyvinyl sponge is able to control the temporary hernia produced by excision of a wide area of the dog abdominal musculature, and it becomes firmly incorporated into the fibrous tissue forming the scar.

There is a danger that sutures will cut through the sponge if it is sewed under too much tension. It remains to be seen whether postoperative coughing and straining will dislodge the sponge in human patients. The sponge is sufficiently elastic to tolerate some stretching—much more so than wire or nylon mesh.

As two layers fuse to form one, there is no great advantage in using them in preference to a single thicker layer, except that it has thus far been impossible to produce Ivalon sponge without some variation in the size of holes in the texture. By using two layers it is possible to vary their relative positions so that no large defects coincide.

Infection and encapsulation of the sponge occurred in 1 of 13 dogs in which polyvinyl sponge was used. As no hernia was seen in this dog at any time, it is probable that the sponge had remained fixed for some time before the granulation tissue at its edge and in the interstices was digested by the enzymes in the pus. It is possible that had free drainage and local and systemic antibiotic therapy been instituted early, the result in this dog might have been better. This single failure emphasizes the point that infection is the greatest threat in the use of any material for repair of hernial defects and that polyvinyl sponge, despite its biologic inertness, is no exception.

The ability of tantalum mesh to control large hernias has been amply demonstrated in clinical experience and was shown again in the present experiments. In the dogs in which it was used there was a higher incidence of collection of fluid around the prosthesis than was noted with use of polyvinyl sponge.

Only trial of polyvinyl sponge in patients can determine whether or not it represents an improvement over present methods of repairing large hernias. We feel that results of the present study warrant a trial of polyvinyl sponge as a prosthesis for strengthening repairs of hernia in man.

TENSILE STRENGTH OF DEFECTS IN MUSCLE REPAIRED WITH POLYVINYL SPONGE

Experiments were performed to test whether polyvinyl sponge filling a defect in the abdominal musculature of the rabbit gains in tensile strength as healing occurs. Examination of microscopic sections of the sponge inserts shows that there is early invasion of the interstices, first with a very few fibroblasts which rapidly increase to form a cellular mass which is in continuity with the healing zone at the junction of sponge and muscle. The sponge later appears microscopically in cross section as islands of the material with relatively little reaction about them in a dense mass of mature scar tissue.†

There is some difficulty in testing the tensile strength of an implant because it depends partly upon the strength of the suture line between the sponge and the normal tissue and partly upon the strength of the invaded sponge itself. Most experi-

† References 7 and 8.

mental methods have employed some variation of a linear stretch tensiometer. These are not suitable for testing the tissue containing a circular or oval prosthesis because the disrupting force will not always be at right angles to the suture line.

The principle of inflation of a cavity with air is suitable for testing the strength of a prosthesis in its wall because tension is put at right angles to any junction line. Harvey and Howes,[11] when investigating the effect of high-protein diet on wound healing, made incisions into the stomach of the rat and tested the strength of the suture line by inflation of the organ with air after ligation of its cardiac and pyloric ends. A similar technique was used by Lanman and Ingalls,[12] who tested incisions in the abdominal wall of normal and scorbutic guinea pigs. Meade,[13] searching for a method of testing the tensile strength of the paralyzed diaphragm, found that when the abdomen was inflated air escaped through the pelvic or diaphragmatic hiatuses before the diaphragm ruptured. We encountered this difficulty when attempting to test the strength of prostheses in the abdominal wall of the rabbit by inflating the abdomen. Meade solved his problem by removing the pieces of muscle from the diaphragm and testing them on a conventional tensiometer. He noted that results varied according to the area of muscle taken, the direction of the fibers relative to the direction of tension, the initial stretching when the specimen was taken, and the varying times between death and testing.

Botsford,[14] Preston,[15] and Douglas ‡ have described methods applicable to linear incisions only but have discussed many of the errors and difficulties associated with testing tensile strength of animal tissues.

The method to be described has been evolved with these considerations in mind.

Experimental Method.—Large albino rabbits weighing from 3.5 to 5.5 kg. were used. With the animal under intravenous pentobarbital anesthesia and with full aseptic conditions, a long midline abdominal incision was made through skin and subcutaneous tissues, which were reflected from the abdominal muscles. There is a clean plane of cleavage here in the rabbit, and the procedure is almost bloodless.

The external oblique muscle was thus exposed and with a circular razor punch, four defects each 1 cm. in diameter, were made in that muscle, two on either side of the midline. The upper pair were 2.5 cm. from the costal margin and 7 cm. above the lower pair. All defects were 2 cm. lateral to the edge of the corresponding rectus sheath. Into each defect was sutured a circular piece of polyvinyl sponge 3 mm. thick which had previously been cut with the same razor punch. 0000 cotton suture material was used on a small needle, care being taken to include as little tissue and sponge as possible. Sutures were placed at each "hour" on the circle. The subcutaneous tissue was closed with gut and the skin with cotton.

The animals were killed at varying times thereafter, pentobarbital being used intravenously, and were rapidly skinned. Only filmy adhesions had formed between the subcutaneous tissues and fascia over the external oblique muscle in most cases. The whole thickness of the abdominal wall was removed from the animal and placed on a dissecting board with the peritoneal side uppermost. The peritoneum, transverse abdominal and internal oblique muscles were then dissected from the external oblique muscle. There is an easy plane of separation in the medial two-thirds of the abdominal wall, and only light touches of a scalpel were necessary to complete this stage. There were no adhesions between the deep surface of the sponge and

‡ References 16 and 17.

the internal oblique muscle, a thin layer of areolar tissue having formed which was in continuity with the fascial sheath on the deep surface of the external oblique muscle.

By keeping the muscle in isotonic sodium chloride solution after its removal from the animal and by testing it soon after death it was usual still to have involuntary twitching present at the beginning of the test.

Four samples of sponge were thus available for testing. Three equal-sized pieces—one upper and one lower, each containing sponge in the center, and one

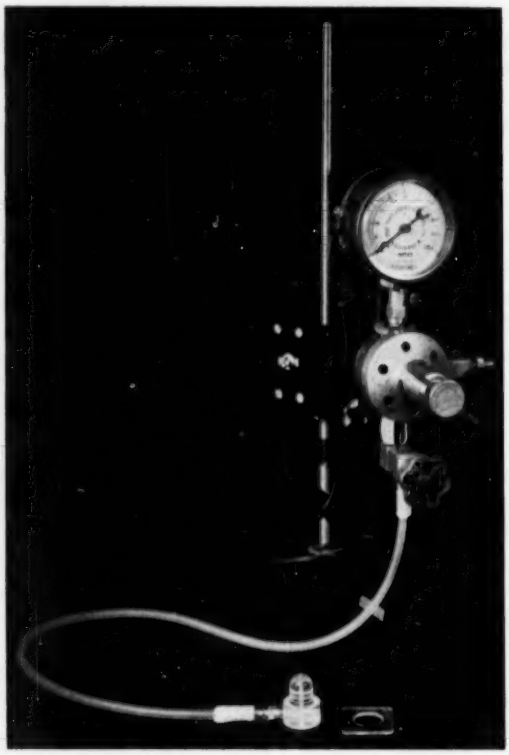


Fig. 6.—Photograph of tensiometer, showing the Lucite dome attached to pressure gauge fitted with agitator. Alongside the dome is the template used for cutting the specimens from the external oblique muscle.

piece from between and slightly lateral to them, composed of normal muscle—were cut from each external oblique muscle with use of a plastic template.

The tensiometer was machined from Lucite, as shown in Figure 6. The six specimens were in turn draped without tension over the hemispherical dome, separated from it by a piece of condom rubber, and were fixed in place with No. 4 braided silk. Care was taken not to tear the muscle fibers. The rubber was found necessary because the early specimens in which invasion by fibrous tissue was incomplete were still porous. Its presence beneath the muscle did not alter the point of rupture. At very low tensions (< 9 gm. per cm.) condom rubber distends

rapidly until it ruptures. During the tests the rubber ruptured almost simultaneously with the specimen. Mr. R. P. Halstead, of the Section of Biophysics, made the Lucite dome and assembled the apparatus.

The dome was connected to a source of compressed air through a reducing valve and pressure gauge. The pressure was slowly increased until the specimen under test ruptured, at which point the tensile strength was measured. The rate of increase in pressure materially alters the breaking point of any structure. With practice it was possible to adjust the regulator so that the pressure rose at a steady rate of 25 cm. Hg (5 lb. [2.3 kg.] per sq. in.) in each 30 seconds. A continuous agitator was fitted to the pressure gauge to make it record evenly. Just before the specimen ruptured there was a noticeable increase in its size and the gauge ceased moving. This point of maximal pressure reached coincided with rupture of the specimen. If the pressure was applied suddenly, rupture occurred without any warning as the pressure was still increasing, and no exact end-point was obtainable.

TABLE 1.—*Tensile Strength of Polyethylene Film as Determined by this Method*

	Tensile Strength, Gm./Cm.		
Test No.	0.002"	0.003"	0.006"
1	439.5	615.3	1,389
2	474.7	632.9	1,310
3	439.5	632.9	1,336
4	465.9	624.1	1,266
5	457.1	632.9	1,231
6	465.9	650.5	1,301
7	457.1	624.1	1,275
8	474.7	641.7	1,319
9	457.1	632.9	1,301
10	448.1	650.9	1,283
Mean	458.0	633.8	1,301
Greatest deviation from mean	18.5 (4%)	18.5 (2.9%)	88.0 (6.7%)

Since the form of the specimen under test is that of a hemisphere, the tension in the muscle or in the muscle with the sponge insert can be calculated by using the formula for surface tension of a sphere, the internal pressure being known.

$$\text{Surface tension} = \frac{\text{pressure} \times \text{radius of sphere}}{2}$$

At the beginning and end of each series of measurements, the pressure gauge was calibrated against a mercury manometer. Values for tensile strength are expressed as grams per centimeter.

Sources of Error.—In this, as in other methods, there are sources of error.

1. In Measurement: In order to determine the errors in measurement, 10 identical pieces of sheets of plastic material (polyethylene film) of three different thicknesses were tested for tensile strength by this method. Each piece was checked with a micrometer for thickness, and it is likely that there were but few flaws in the small area used. The area of film was the same as that of the muscle tested. Tying the film over the plastic dome results in some creasing and infolding, especially with the thickest film. The same happens with muscle to a slighter degree.

As shown in Table 1, there is an error in measurement of about 5%.

2. Variation in Normal Muscle: Botsford [14] and Douglas [18] noted wide variation in the normal values for the skin and fascia they were testing. Such variation

also occurred in this experiment and is probably caused by differences in age, sex, size, and other factors. The delay between killing the animal and testing was kept to a minimum and was reasonably uniform throughout the study. After removal from the body, the muscle was kept thoroughly moistened with isotonic sodium chloride solution.

Table 2 shows the values obtained for normal external oblique muscle from 10 rabbits. The areas tested were the same as used in the animals with inserts of plastic sponge, although the means show little variation, there is a wide discrepancy between results in some animals. Because of this, each animal in the series was made to provide its own control specimens and the tensile strengths of these were compared with those of the areas containing sponge.

3. Presence of Sutures: During the early postoperative period the strength of union between insert and muscle depends upon the sutures in addition to any fibrous union. Because continuity of the fascial sheath of the muscle developed over

TABLE 2.—*Tensile Strength (Gm./Cm.) of Normal External Oblique Muscle*

Rabbit No.	Left			Right		
	Upper	Middle	Lower	Upper	Middle	Lower
1	1,213	1,336	1,266	1,037	1,195	1,143
2	1,248	1,301	1,600	1,301	1,600	1,723
3	1,283	1,477	1,362	1,442	1,371	1,477
4	1,582	1,670	1,863	1,406	1,406	1,617
5	1,617	1,582	1,319	1,108	1,512	1,336
6	1,459	1,178	1,653	1,670	1,336	1,389
7	1,108	809	897	984	870	686
8	879	967	1,020	1,002	1,125	861
9	967	870	580	809	861	686
10	1,283	1,125	1,002	1,231	1,178	861
Mean	1,264	1,232	1,256	1,190	1,245	1,178

the sponge later, it was not possible to remove the sutures without materially altering the integrity of the junction. In a few specimens one or two stitches had cut out either of muscle or of sponge. If there was no gross gaping between muscle and insert, these specimens were included in the series. Douglas [18] has shown that cotton loses its tensile strength rapidly when implanted in the tissues and retains but 13 to 20% of its original strength by the end of the second month. By the end of the fourth month, the tensile strength of cotton is almost nil.

For comparison, a small group of rabbits was tested after a semicircular incision had been made in the external oblique muscle at the usual site of insertion of a sponge and sutured at once with five cotton sutures. The diameter of the semicircle was 1 cm. and was at right angles to the fibers of the muscle.

4. Other Sources: The external oblique muscle was usually very easily removed from the rest of the abdominal musculature, but occasionally some difficulty was experienced. Care was taken to dissect at the expense of the internal oblique muscle, but undue tension during this stage could alter results. Most trouble was encountered where the blood vessels perforate from the deeper layers to reach the external oblique muscle where they break up into very small vessels. These branches were divided as close to the internal oblique muscle as possible. No correlation was noted between the site of these perforating branches and the site of rupture.

Results.—1. Sutured Incisions: The results of this series show the progressive increase in tensile strength of an incision in the rabbit external oblique muscle which had been sutured with cotton. Data are presented both as grams per centimeter and as percentages of normal in Table 3. Normal values were the mean of tests on the control areas. For graphic representation the percentage of normal tensile strength has been plotted against the time following suturing of the wound (Fig. 7).

TABLE 3.—*Tensile Strength of Sutured Incisions*

		Tensile Strength, Gm./Cm.					Percentage of Normal			
			Upper		Lower		Upper		Lower	
Days	Rabbit No.	Normal	Left	Right	Left	Right	Left	Right	Left	Right
7.....	1	1,270	255	281	220	246	20.1	22.1	17.3	19.4
21.....	2	1,253	440	431	485	422	35.1	34.4	38.7	33.7
28.....	3	1,328	536	563	598	624	40.4	42.4	45.0	47.0
56.....	4	1,411	633	735	642	678	44.9	52.1	45.5	48.1
84.....	5	1,090	501	527	571	510	46.0	48.3	52.4	46.8
112.....	6	1,200	580	651	633	554	48.3	54.2	52.7	46.2
140.....	7	848	509	492	475	528	60.0	58.0	56.0	62.3

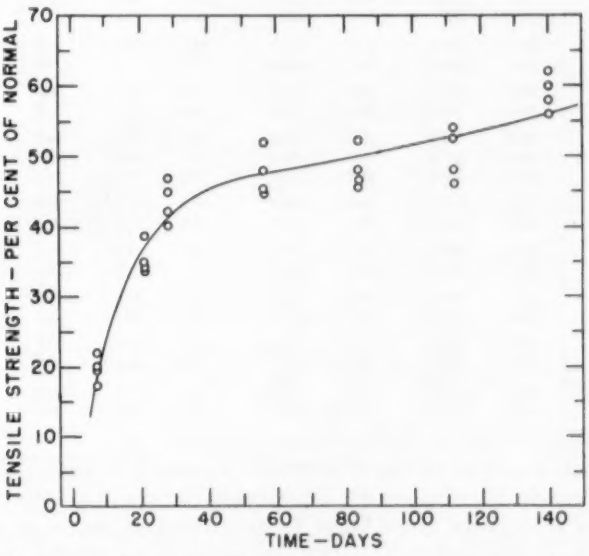


Fig. 7.—Chart of tensile strength of healing incisions in the external oblique muscle of the rabbit which have been sutured with cotton.

There is close approximation of the results for each animal at any given time, and the strength of the wounds is seen to increase rapidly during the first four weeks and more slowly thereafter. The curve obtained is exponential and is similar to that obtained in normal healing of other tissues.

At the end of 20 weeks the wound has gained about 60% of the tensile strength of the intact muscle, but its strength still appears to be increasing.

2. Sponge Implants: In Table 4 the values for the four test specimens from each animal are shown separately, together with the mean value for the strength of normal muscle from the same animal.

There is marked discrepancy in the absolute values obtained for the tensile strength of the polyvinyl sponge insert from animal to animal at the same time interval. More uniformity is obtained when these results are expressed as a percentage of the tensile strength of normal muscle from the same animal.

TABLE 4.—*Results of Experiments in Rabbits in Which Four Pieces of Polyvinyl Sponge Have Been Implanted Into the External Oblique Muscle*

		Tensile Strength, Gm./Cm.					Percentage of Normal				
			Upper		Lower		Upper		Lower		
Days	Rabbit No.	Normal	Left	Right	Left	Right	Left	Right	Left	Right	Mean Value
0	1	994	180.8	162.7	225.0	180.8	18.2	16.4	23.6	18.2	19.1
	2	1,152	162.7	180.8	171.8	198.9	14.1	15.7	14.9	17.3	15.5
	3	901	180.8	180.8	162.7	180.8	20.1	21.1	18.1	20.1	19.9
7	4	1,069	202.2	202.2	263.7	272.5	18.9	18.9	24.7	25.5	22.0
	5	1,112	263.7	254.9	254.9	263.7	23.7	22.9	22.9	23.7	23.3
10	6	1,292	325.2	404.3	325.2	316.4	25.2	31.3	25.2	24.5	26.5
	7	1,398	404.3	439.5	386.8	465.9	28.9	31.4	27.7	33.3	30.3
12	8	848	413.1	474.7	457.1	404.3	48.7	56.0	53.9	47.7	51.6
	9	1,235	228.5	263.7	527.4	527.4	18.5	21.4	42.7	42.7	31.3
14	10	1,235	360.4	369.2	386.8	307.7	29.2	29.9	31.3	24.9	28.8
	11	1,372	316.4	307.7	263.7	360.4	23.1	22.4	19.2	26.3	22.8
21	12	1,275	342.8	342.8	369.2	351.6	26.9	26.9	29.0	27.6	27.6
	13	1,262	263.7	219.8	351.6	219.8	20.9	17.4	27.9	17.4	20.9
28	14	1,468	545.0	421.9	421.9	448.3	37.1	28.7	28.7	30.5	31.3
	15	1,446	395.6	351.6	439.5	334.0	27.4	24.3	30.4	23.1	26.3
	16	1,353	369.2	369.2	325.2	334.0	27.3	27.3	24.0	24.7	25.8
42	17	1,455	773.5	755.9	615.3	808.7	53.2	52.0	42.3	55.6	50.8
	18	1,029	334.0	404.3	361.5	298.9	32.5	39.3	35.1	29.0	34.0
56	19	1,229	442.0	462.4	591.6	571.2	36.0	37.6	48.1	46.5	42.0
	20	1,229	707.2	673.2	663.0	664.4	57.5	54.8	53.9	54.1	55.1
84	21	1,046	439.5	588.9	334.0	404.3	42.0	56.3	31.9	38.7	42.2
	22	849	298.9	272.5	263.7	404.3	35.2	32.1	31.1	47.6	36.5
112	23	1,205	439.5	632.9	439.5	553.8	34.7	50.0	34.7	43.8	40.8
	24	1,025	527.4	457.1	527.4	545.0	51.5	44.6	51.5	43.2	50.2
140	25	1,529	861.4	1,105.0	773.5	975.7	56.3	78.2	50.6	63.8	62.2
	26	1,178	439.5	527.4	545.0	457.1	37.3	44.8	46.3	38.8	41.8

In the wounds tested on the day of insertion (Rabbits 1, 2, and 3), about 20% of the tensile strength of normal muscle is present in the sponge as sutured into the defect. In these animals the insert began to stretch as soon as the pressure was raised above 15 cm. Hg, and in all except one specimen the stitches cut through the edge of the sponge. In the exception, the sponge itself tore.

Invasion with fibrous tissue is rapid, and at seven days nearly the whole insert is filled with early granulation tissue. At this stage rupture is through the center of the sponge, which appears the weakest place. By the 10th day the sponge is completely invaded and, with only one or two exceptions, rupture takes place at the suture line.

It is interesting to note that when each animal is considered separately, there is little variation in the four values obtained for the healing sponge. Multiple

incisions inflicted at the same time heal at the same rate and this implies some systemic control of wound repair. It would appear that the presence of polyvinyl sponge does not upset this control.

The average tensile strength of the four specimens, expressed as a percentage of normal, has been plotted against time (Fig. 8). The sponge has gained in strength after 40 to 60 days. At no time up to 140 days did the strength of the repaired defect approach that of the normal muscle, but it was approximately half as strong.

The curve of the increase in tensile strength of a sutured incision has been superimposed on Figure 8, and it is possible to infer that the healing of the implants is similar to that of the normal incision.

Comment.—This method of measuring tensile strength has disadvantages in common with all tests that require removal of tissue from the animal. An advantage

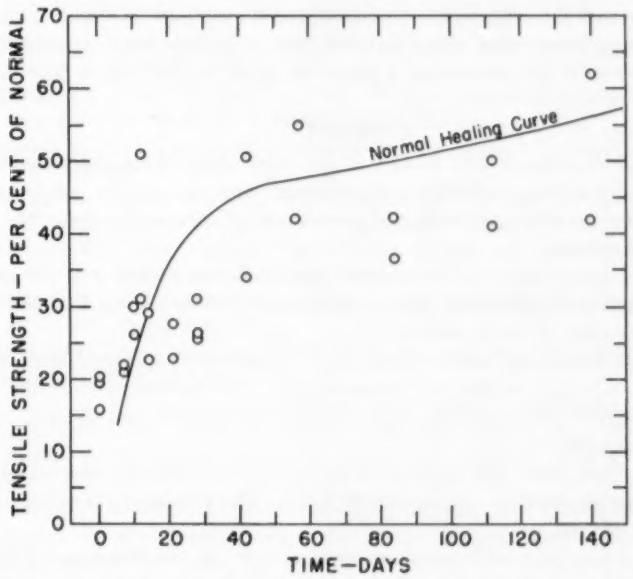


Fig. 8.—Chart of tensile strength of healing defects in the external oblique muscle of the rabbit which have been repaired with polyvinyl sponge implants.

is that it enables tension to be put at right angles to the curved or circular incisions necessary when an implant is placed in a defect in the abdominal muscles.

From a study of the simple curved incisions closed by suture, it is seen that healing in the external oblique muscle of the rabbit follows a similar pattern to healing in skin [19] and aponeurosis.§ The close agreement between the results from four incisions in each animal is further evidence of the systemic control of wound healing.

Skin wounds attain their maximal strength in 14 to 21 days [20]; aponeurosis in 200 to 300 days. Muscle would appear to increase in strength rapidly for 28 to 35 days and gradually over the next 15 weeks and more. There is difficulty in con-

§ References 17 and 20.

structing a curve from the results of the sponge implants, but the pattern is somewhat similar to that seen in other tissues. The rate of increase is rather more rapid in the first 30 to 60 days than thereafter.

The weakest point is the suture line, and in practically every specimen tested rupture occurred here. In this study the sponge was sutured edge-to-edge to the muscle. If left unsutured or anchored only with two stitches, there is poor union between the two edges. A layer of areolar tissue rapidly covers the superficial and deep surfaces of the sponge and becomes continuous over the edge. It is essential that the sponge be sutured carefully in position if healing is to be sound.

No infection was encountered in this series of experiments on tensile strength, and the effect of infection on the healing of polyvinyl sponge into the tissues cannot be judged.

If polyvinyl sponge is to be used in human surgery to reinforce a hernia repair, it is probable that the edge would be overlapped on the normal tissue. This should give a stronger repair and allow fixation over a larger area; consequently, the tendency shown in this series for rupture to occur at the suture line might be lessened.

SUMMARY

Defects approximately 8 by 10 cm. in size were made in the abdominal walls of dogs by excising portions of both rectus abdominis muscles with the overlying rectus sheath and the underlying sheath and peritoneum. Omentum was sutured to free edges of peritoneum.

In each of seven dogs that underwent simple closure of skin and subcutaneous tissues, herniation developed for four to six weeks. The herniation had disappeared spontaneously after 10 to 12 weeks.

In none of seven dogs with a single layer of polyvinyl sponge 3 mm. in thickness sutured to bridge the gap did hernia develop. One became infected and did not remain in position; the remainder were firmly incorporated into the scar tissue in the abdominal wall.

In none of six dogs with a double layer of polyvinyl sponge sutured to bridge the gap did hernia develop, and all healed firmly. The two layers of sponge became amalgamated as one.

In none of five dogs with tantalum mesh used to fill the defect and studied for comparison did hernias develop. Four had transient subcutaneous collections of fluid during the postoperative course.

Experiments were performed to test whether polyvinyl sponge filling a defect in the abdominal musculature of the rabbit gains in tensile strength as healing occurs.

A method is described for measuring the tensile strength of animal tissues, which is applicable to prostheses used in the repair of defects.

The healing of 104 implants of polyvinyl sponge in the external oblique muscle of 26 rabbits has been studied.

Defects in the muscle repaired with polyvinyl sponge gained in tensile strength fairly rapidly for approximately 40 days and slowly, if at all, thereafter. Values of 40 to 60% of normal were found between 60 and 140 days after implants were made.

Variation in these data was sufficiently great that precise comparison with the increase in strength of healing sutured wounds in the same area cannot be made, but the time sequence seemed generally similar.

REFERENCES

1. Babcock, W. W.: Metallic Sutures and Ligatures, S. Clin. North America **31**:1435, 1947.

2. Lam, C. R.; Szilagyi, D. E., and Puppendahl, M.: Tantalum Gauze in the Repair of Large Postoperative Ventral Hernias, Arch. Surg. **57**:235, 1948.

3. Witzel, O.: Über den Verschluss von Bauchwunden und Bruchpforten durch versenkte Silberdrahtnetze (Einheilung von Filigranpelotten), Zentralbl. Chir. **27**:257, 1900.

4. Mair, G. B.: The Use of Whole Skin Grafts as a Substitute for Fascial Sutures in the Treatment of Hernias, Am. J. Surg. (n. s.) **69**:352, 1945.

5. Gallie, W. E., and LeMesurier, A. B.: The Transplantation of the Fibrous Tissues in the Repair of Anatomical Defects, Brit. J. Surg. **12**:289, 1924-1925.

6. Grindlay, J. H., and Clagett, O. T.: A Plastic Sponge Prosthesis for Use After Pneumonectomy: Preliminary Report of an Experimental Study, Proc. Staff Meet., Mayo Clin. **24**:538, 1949.

7. Grindlay, J. H., and Waugh, J. M.: Plastic Sponge Which Acts as Framework for Living Tissue: Experimental Studies and Preliminary Report of Use to Reinforce Abdominal Aneurysms, A. M. A. Arch. Surg. **63**:288, 1951.

8. Schilling, J. A.; Favata, B. V., and Radakovich, M.: Studies of Fibroplasia in Wound Healing, Surg., Gynec. & Obst. **96**:143, 1953.

9. Cumberland, V. H.: A Preliminary Report on the Use of Prefabricated Nylon Weave in the Repair of Ventral Hernia, M. J. Australia **1**:143, 1952.

10. Koontz, A. R.: Experimental Results in the Use of Dead Fascia Grafts for Hernia Repair, Ann. Surg. **83**:523, 1926.

11. Harvey, S. C., and Howes, E. L.: Effect of High Protein Diet on the Velocity of Growth of Fibroblasts in the Healing Wound, Ann. Surg. **91**:641, 1930.

12. Lanman, T. H., and Ingalls, T. H.: Vitamin C Deficiency and Wound Healing: An Experimental and Clinical Study, Ann. Surg. **105**:616, 1937.

13. Meade, R. H., Jr.: The Tensile Strength of the Paralyzed Diaphragm: Preliminary Report, J. Thoracic Surg. **2**:503, 1933.

14. Botsford, T. W.: The Tensile Strength of Sutured Skin Wounds During Healing, Surg., Gynec. & Obst. **72**:690, 1941.

15. Preston, D. J.: The Effects of Sutures on the Strength of Healing Wounds: With Notes on the Clinical Use of Annealed Stainless Steel Wire Sutures, Am. J. Surg. **49**:56, 1940.

16. Douglas, D. M.: Tensile Strength of Sutures. I. The B.P.C. Method of Test, Lancet **2**:497, 1949.

17. Douglas, D. M.: The Healing of Aponeurotic Incisions, Brit. J. Surg. **40**:79, 1952.

18. Douglas, D. M.: Tensile Strength of Sutures: II. Loss When Implanted in Living Tissue, Lancet **2**:499, 1949.

19. Localio, S. A.; Casale, W., and Hinton, J. W.: Wound Healing: Experimental and Statistical Study: Experimental Observations, Surg., Gynec. & Obst. **77**:243, 1943.

20. Howes, E. L.; Sooy, J. W., and Harvey, S. C.: The Healing of Wounds as Determined by Their Tensile Strength, J. A. M. A. **92**:42, 1929.

CEREBRAL EFFECTS OF EXPERIMENTAL HYPOTHERMIA

JOHN C. CALLAGHAN, M.D.
DONALD A. McQUEEN, M.D.
JOHN W. SCOTT, M.D.
AND
W. G. BIGELOW, M.D.
TORONTO, CANADA

SINCE hypothermia was first suggested as a technique which would permit intracardiac surgery under direct vision,* the possibility of a deleterious effect of the low body temperatures upon the brain has been considered. It has been observed that animals † and humans ‡ enter a narcotic state when the rectal temperatures fall below 30 C. Although no gross cerebral damage has been noted from simple cooling in dogs, it was considered expedient to study the cerebral effects of cooling more carefully and to search for any evidence of permanent injury to the central nervous system.

Monkeys, being the highest order of animals available, were chosen for this study.

Survival rate, electroencephalographic changes, behavior test performance, reflexes, and changes in cardiovascular and respiratory control were selected as factors in the assessment of cerebral function.

Simpson [7] investigated the effects of lowering the body temperature of the monkey under ether anesthesia, with rewarming and survival from a temperature as low as 14 C. in one animal. Fay and Smith [8] found no permanent neurological changes in humans following induced hypothermia to temperatures as low as 26 C. Fuhrman and Field [8] have found that rat cerebral cortex could recover its normal function as determined by oxygen consumption and anaerobic glycolysis measurements for one hour exposure to a temperature of 0.2 C.

Fazekas and Himwich [9] studied the oxygen content of blood from the superior saggital sinus and the femoral artery of nine dogs during the course of cooling to 26 C. A decreased arteriovenous difference was found with a slower blood flow indicating a fall in the rate of cerebral metabolism.

From the Department of Surgery, University of Toronto, Faculty of Medicine.

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Fellow in Surgery (Dr. Callaghan); Fellow in Physiology (Dr. McQueen); Director, EEG, Laboratory, Toronto General Hospital (Dr. Scott), and Assistant Professor of Surgery (Dr. Bigelow).

* References 1 and 2.

† References 1 to 4.

‡ References 5 and 6.

METHODS

Ten immature monkeys (Macacus rhesus) weighing between 1.5 and 3.7 kg. were used in this investigation.

Training and Behavior Tests.—In order to determine whether cooling had produced mental deterioration, two simple tests were used.

The first problem presented was that described by Warden, Koch, and Fjeld.[10] A dish of food was placed just beyond the reach of the animal. Three pieces of string, each 5 in. (13 cm.) in length, were placed between animal and dish, one attached to the dish, the others lying free. The rapidity with which the animal selected the correct string was observed.

The second task consisted of manipulating light wooden T-sticks to obtain food as described by Klüver,[11] and Warden, Koch, and Fjeld.[10]

In addition, general observations of cage behavior with other monkeys and ability to elude capture were noted during the 14-day period of training.

Electroencephalographic Studies.—At the end of this period of training and observation the 10 monkeys were given 0.44 mg. per kilogram body weight of thiopental (Pentothal) sodium intravenously. This produced a light anesthesia which facilitated the handling of the animals.

After the animal was anesthetized, four small curved needles were introduced into the scalp as electrodes. Two of these were placed in the midline, one just above the supraorbital ridge, the other over the occipital protuberance. The other two electrodes were placed one on either side, 1.0 cm. above each ear.

The electroencephalographic observations on the first four animals were made with a continuous recording six-channel Mark III Grass instrument.§ The remaining six animals were studied by means of a single channel EEG amplifier with cathode ray oscilloscope. Representative samples were photographed throughout the experiment.

Cooling and Rewarming Technique.—After records were observed at normal body temperature, the animals were placed in a specially designed ice-water bath kept at 10 C. which permitted almost total immersion while maintaining a position requisite for a clear airway.

Continuous electrocardiographic tracings were observed with a Smith and Stone ‖ instrument, with use of subcutaneous limb leads.

The temperature of the animals were recorded by a mercury laboratory thermometer placed a minimum of 10.0 cm. into the rectum.

Continuous visual observation of shivering, level of consciousness, active movement, reflexes, breathing, and color of the tongue and palms were made during the experiment.

When the rectal temperature reached 1 to 2 degrees above the desired 20 C., the animal was removed from the bath, dried with a towel, and observed for periods up to two hours at that temperature.

After the low rectal temperatures were maintained for this period, the animals were placed in a water bath at a temperature of 40 C. or subjected to radiofrequency rewarming as described in another study.[17]

Continuous intranasal oxygen was given throughout the experiment.

After normal body temperature was reached, the animals were watched closely for a period of from 15 minutes to 2 hours and returned to their cages as their general condition indicated.

Daily observations were made of their appetite, behavior, and ability to perform the tests they had learned previously. Each animal underwent a complete physical examination 24 hours after cooling and again within a two-week period following the cooling.

Five of the animals were recooled at a later date, and of these, 2 underwent hypothermia for a third time, making a total of 17 inductions of hypothermia to body temperatures of 20 C. in the 10 monkeys studied.

OBSERVATIONS

1. *Survival.*—All 10 animals survived the lowering of the body temperature to 20 C. or less, and at no time during the cooling process did the condition of the monkeys cause special concern. The time taken for the body temperature to fall

§ Grass Instrument Co., Quincy, Mass.

‖ Smith and Stone Co., Georgetown, Ont.

from normal (39 C.) to 20 C. varied between 38 and 90 minutes. The rewarming period lasted from 42 minutes to 2 hours 9 minutes. The body temperatures of the animals were allowed to remain below 21 C. for periods ranging from 2 minutes to 1 hour 25 minutes, the average being 32 minutes.

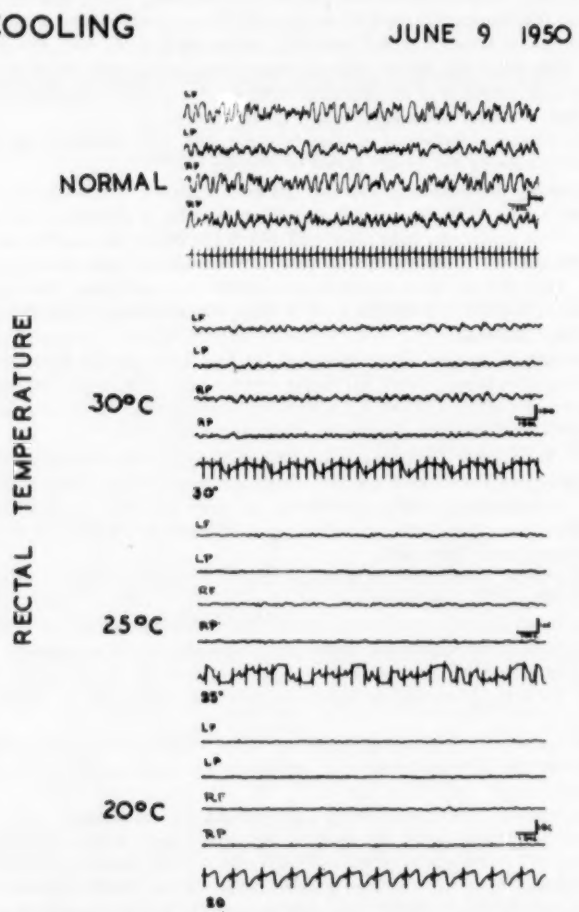

Chart 1.—Changes in EEG activity during reduction of body temperature.

2. *Cardiovascular System.*—The cardiac rate gradually fell as the body temperature was lowered. The first recorded heart rates varied between 120 and 200 beats a minute, and the lower rate observed was 20 beats a minute. The heart rates fell to between 13 and 30%, with an average of 21% of the precooling rate on lowering the body temperature to 20 C. The continuous electrocardiographic studies in the seven experiments in which they were used disclosed the usual abnormalities that accompany the lowering of body temperature,[1] consisting of decreased rate, widen-

ing of the QRS complex, inversion of the T wave and periods of temporary idioventricular rhythm. On one occasion transient electrocardiographic evidence of ventricular fibrillation lasting two seconds was observed.

From a previous study,[1] rectal temperatures were found to be within 1 degree (C.) of the temperature of blood in the heart and therefore a satisfactory index of cerebral temperature.

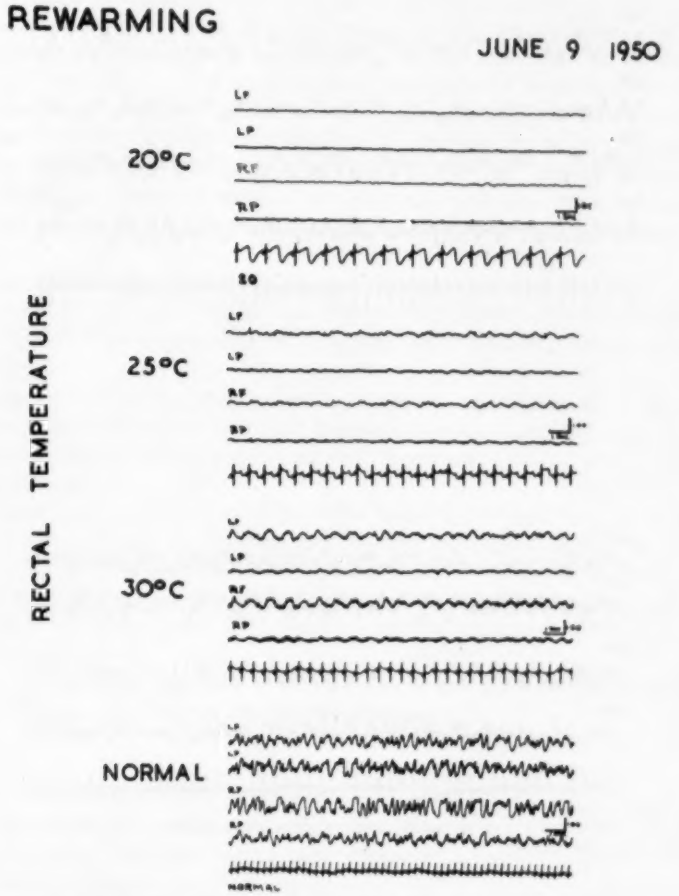

Chart 2.—Changes in EEG activity during rewarming.

3. *Respiratory System.*—Cyanosis was not observed during the cooling period. As the body temperatures fell, the tongue and the palms became and remained pink in color. During the rewarming period a return to normal color or occasionally duskiness was observed. The latter was transient in its appearance. This is identical to observations in dogs at similar temperatures.[2] Spontaneous respirations were present at all times during the 17 coolings. The rate of respiration fell markedly from rates of 25 to 50 breaths a minute at the onset of cooling to rates of 4 to 16

breaths a minute at body temperatures of 20 C. The maintenance of spontaneous respirations at such temperatures was in contrast with the behavior of dogs, whose respirations usually cease between 22 and 24 C.

4. *Electroencephalographic Changes.*—A diminution in EEG activity occurred rather abruptly, usually between 31 and 33 C. Cerebral activity at these temperatures is obscured intermittently by scalp muscle action potentials produced by shiv-

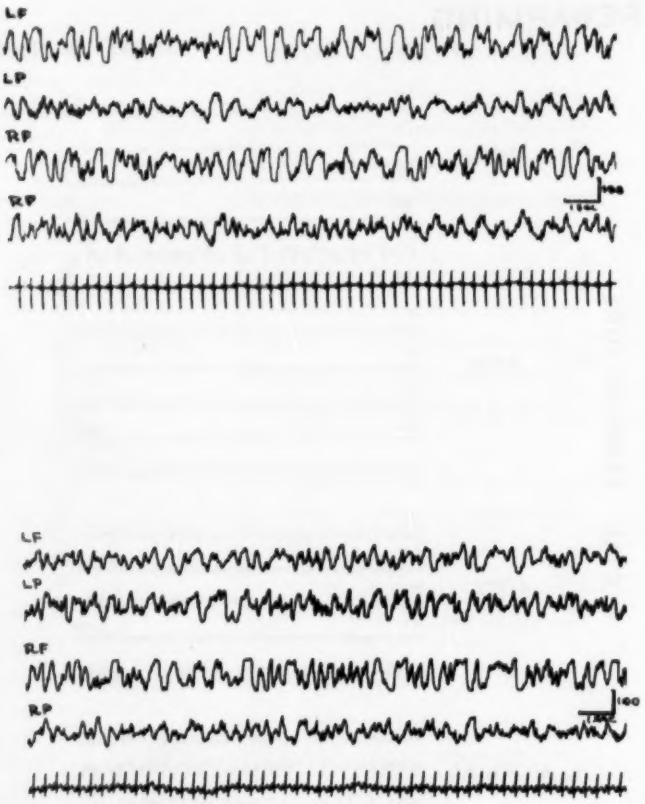

Chart 3.—Upper tracing made at start of experiment, compared with lower tracing, made two weeks after the cooling.

ering. As shown in Figure 1, the greatest change was seen in the parietal region where all activity has been depressed leaving only a delta rhythm of less than 40 μv. with a frequency between 1 and 2 cycles per second (cps). In the frontal regions the fast activity is greatly reduced and there only the slow delta rhythms persist, most of them not exceeding 100 μv.

At 25 C. the pattern is similar but of lower voltage. The peak voltages from the frontal regions now is only 50 μv. and from the occipital regions less than 25 μv. At this temperature there is still a small amount of 5 to 7 cps activity from the frontal regions.

When the rectal temperature has reached 20 C., there is a slight wavering of the base line at 2 cps in the frontal regions, but no appreciable activity is seen from the parietal regions and occiput. There is an electrocardiographic artifact evident in the tracings at this temperature. Increasing the amplification showed that there were no other wave forms present. In three of the animals no cortical activity whatsoever could be demonstrated in the EEG at 20 C.[21]

Repeated coolings or maintaining the animals for prolonged periods of lowered body temperature produced no further change in the EEG tracings.

During rewarming no new rhythms appeared and the changes which had occurred during the cooling period reappeared in reverse order but with an apparent lag of 1 or 2 degrees (C.), the reappearance of the patterns being slightly delayed during rewarming (Fig. 2). When the rectal temperature reached the order of 33 C., many faster rhythms appeared which masked the higher voltage delta activity. There were no late effects observed (Fig. 3).

5. *Reflexes and Active Movement.*—The animals recovered from refrigeration in a manner that could not be distinguished from emergence from light barbiturate anesthesia.

Spontaneous movements were first noticed between 32.2 and 36 C. on rewarming. Response by flexion of the leg was observed on painful stimulus between 29 and 36.6. Ataxia was noted during the two-hour period following return to normal body temperature.

6. *Behavior.*—After this transient ataxia, there was no impairment in the ability of the animals to elude capture and their cage behavior was normal in every respect. Rectal temperatures remained normal. Muscle power and tone, as well as reflexes, remained normal.

The string tests and the T-stick problems were undertaken daily for a period of 10 to 14 days and were in all instances performed swiftly and accurately. On the day following refrigeration, each of the first five animals was paired with an animal which had not undergone cooling and the former were well able to compete for food. One sickly, emaciated monkey with chronic diarrhea underwent the cooling with no change in its status.

7. *Radiofrequency Rewarming.*—There was no evidence of deleterious effect of radiofrequency rewarming in the animals studied.

COMMENT

The normal status of all 10 monkeys after cooling to 20 C. would suggest that hypothermia produces no deleterious effect upon the brain.

When compared with our earlier experiments with dogs, the monkey demonstrates a greater tolerance to a body temperature of 20 C., which we have felt may be in part the result of species difference. Another important factor may well be their immature state. Support for this was found in observations of the relative safety of cooling of immature monkeys, as compared with adults of the same species in other experiments.[13]

The same slowing of the heart and respiratory rate together with deep unconsciousness was noted as cooling progressed, and it followed a pattern similar to that in dogs.¶

¶ References 1 and 2.

Our precooling records resemble closely those of Kennard and Nims [12] for unanesthetized monkeys of this age. Ten Cate, Horsten, and Koopman [14] have investigated the effects of cold on the EEG of the curarized rat. The findings with the monkey are in many respects similar.

In both series the primary effects are changes in amplitude and wave form rather than in frequency. Brazier [15] has discussed foci for the slow waves of deep sleep in the frontal regions, and we observed slow waves (2 or 3 cps) which became prominent usually between 31 and 32 C. resembling the delta activity of sleep. Hoagland, Himwich, Campbell, Fazekas, and Hadidian [16] have discussed the presence of such waves in barbiturate narcosis, in hypoglycemia, and with increased intracranial pressure.

Fay and Smith [5] studied human reflex responses under induced hypothermia and found that deep and superficial reflexes were abolished at 25.5 C. during cooling and returned at approximately 26.6 C. on rewarming. Such a lag, if real, would correspond with the delay in the return of the EEG activity in our animals during rewarming.

Lyman and Chatfield [18] studied electrocorticograms and cortical temperatures in hibernating woodchucks (Marmota monax) at temperatures as low as 6 C. They describe slow nondescript spontaneous activity, sporadic in nature, which at 11 C. becomes bursts of spontaneous activity.

We have felt the important feature is the complete absence of any electroencephalographic evidence of cerebral damage, this judgment being supported by the normal behavior patterns of the animals following cooling. This is in agreement with the early clinical successes both by us [20] and by others [19] during recent applications of hypothermia for cardiac surgery in humans.

SUMMARY AND CONCLUSIONS

The cerebral effects of hypothermia were studied in 17 experiments in which 10 monkeys were cooled to 20 C., then rewarmed to normal body temperature.

Electroencephalographic studies disclosed a depression of cortical activity during cooling, with little or no activity at 20 C. The rhythms returned in reverse order on rewarming. There was no evidence of cerebral damage.

Cooling to 20 C. had no effect on the aptitude with which the animals subsequently performed tests learned prior to the experiment.

Unconsciousness and loss of motor power and reflexes occurred as the body temperature was lowered, but rewarming resulted in complete recovery.

Radiofrequency rewarming appears to have no deleterious effect on function of the central nervous system.

The reduction of body temperature in monkeys to 20 C. appears to have no permanent ill effects on cerebral function.

Professor C. H. Best, of the Department of Physiology; Dr. E. H. Botterell, of the Division of Neurosurgery, and Professor R. M. Janes, of the Department of Surgery, University of Toronto, cooperated in this study.

REFERENCES

1. Bigelow, W. G.; Lindsay, W. K., and Greenwood, W. F.: Hypothermia: Its Possible Role in Cardiac Surgery, Ann. Surg. **132**:849-866, 1950.

2. Bigelow, W. G.; Callaghan, J. C., and Hopps, J. A.: General Hypothermia for Intracardiac Surgery, Ann. Surg. **132**:531-539, 1950.

3. Hamilton, J. B.; Dresbach, M., and Hamilton, R. S.: Cardiac Changes During Progressive Hypothermia, Am. J. Physiol. **118**:71-76, 1937.

4. Prec, C.; Rosman, R.; Baun, K.; Rodband, S., and Katz, L. N.: The Cardiovascular Effects of Acutely Induced Hypothermia, J. Clin. Invest. **28**:293-306, 1949.

5. Fay, T., and Smith G. W.: Observations on Reflex Responses During Prolonged Periods of Human Refrigeration, Arch. Neurol. & Psychiat. **45**:215-222, 1941.

6. Alexander, L.: Human Exposure to Cold, Item No. 24, File No. XXVI, 37, C. I. O. S., U. S. Army, 1945.

7. Simpson, S.: Temperature Range in the Monkey in Ether Anesthesia, Proc. Physiol. Soc., London, pp. 37-40, 1902.

8. Fuhrman, F. A., and Field, J.: The Reversibility of the Inhibition of Rat Brain and Kidney Metabolism by Cold, Am. J. Physiol. **139**:193-196, 1943.

9. Fazekas, J. F., and Himwich, H. E.: Effect of Hypothermia on Cerebral Metabolsim, Proc. Soc. Exper. Biol. & Med. **42**:537-538, 1939.

10. Warden, C. J.; Koch, A. M., and Fjeld, H. A.: Solution of Patterned String Problems by Monkeys, J. Genet. Psychol. **56**:283, 1940.

11. Klüver, H.: Behaviour Mechanisms in Monkeys, Chicago, Univ. Chicago Press, 1933.

12. Kennard, M. A., and Nims, L. F.: Changes in Normal Electroencephalogram of Macaca Mulatta with Growth, J. Neurophysiol. **5**:325-333, 1942.

13. Bigelow, W. G., and McBirnie, J. E.: Further Experiences with Hypothermia for Intracardiac Surgery in Monkeys and Groundhogs, Ann. Surg. **137**:361-365, 1953.

14. ten Cate, J.; Horsten, G. P. M., and Koopman, L. J.: The Influence of the Body Temperature on the EEG of the Rat, Electroencephalog. & Clin. Neurophysiol. **1**:231-235, 1949.

15. Brazier, M.: The Electrical Fields at the Surface of the Head During Sleep, Electroencephalog. & Clin. Neurophysiol. **1**:195-204, 1949.

16. Hoagland, H.; Himwich, H. E.; Campbell, E.; Fazekas, J. F., and Hadidian, Z.: Effects of Hypoglycemia and Pentobarbital Sodium on Electrical Activity of Cerebral Cortex and Hypothalamus (Dogs), J. Neurophysiol. **2**:276-288, 1939.

17. Bigelow, W. G.; Hopps, J. A., and Callaghan, J. C.: Radio-Frequency Rewarming in Resuscitation from Severe Hypothermia, Canad. J. M. Sc. **30**:185-193, 1952.

18. Lyman, C. P., and Chatfield, P. O.: Hibernation and Cortical Electrical Activity in the Woodchuck (Marmota Monax), Science **117**:533-34, 1953.

19. Lewis, F. J., and Taufic, M.: Closure of Atrial Septal Defects with the Aid of Hypothermia, Surgery **33**:52-59, 1953.

20. Bigelow, W. G.: Hypothermia for Cardiac Surgery, to be published.

21. Scott, J. W.; McQueen, D. A., and Callaghan, J. C.: The Effect of Lowered Body Temperature on the EEG of the Monkey, Electroencephalog. & Clin. Neurophysiol. **5**:465, 1953.

TRICEPS SURAE SYNDROME IN CEREBRAL PALSY

An Operation to Aid in Its Relief

LENOX D. BAKER, M.D.
DURHAM, N. C.

THE PURPOSE of this paper is threefold: first, to stimulate interest and to reevaluate the over-all problem and the need of early surgery in the care of the cerebral palsied child; second, to discuss the various functional disturbances associated with the spastic or tense triceps surae muscle, and third, to describe a surgical procedure directed at restoring control of the function of this muscle and correction of some of the bizarre deformities resulting from its involvement.

During the past decade or more, repeated emphasis on so-called conservative therapy has overshadowed the surgical needs of the patients afflicted with cerebral palsy. During this period, with the exception of McCarroll's instructional course papers,[1] there has been little written on surgery in these children, and no satisfactory operative procedures worthy of the name new has been described. This apparent lack of attention on the part of the orthopedists to a universal problem has existed in spite of widespread public interest and patronage. The mishandling of this problem is another example of our failure to lead and our refusal to follow resulting in obstruction, which, in turn, has forced the case of the cerebral palsy child into the hands of those outside our specialty. Although embarrassing, this is no new position in which the specialty finds itself. The situation is one which can be best remedied by self-appraisal and correction rather than by criticism of those outside the profession who have looked to us for leadership only to be turned away. The observations to be reported in this paper were made at the North Carolina Cerebral Palsy Hospital. The surgery was done at Duke Hospital. Perhaps a discussion of the background of the affiliation of these two institutions would be illustrative of what can be done to keep the cerebral palsy problem in the hands of those who are not overly optimistic but who at the same time realize that the problem is far-reaching in its effects. A few of these children can be rehabilitated. In all instances the family needs sound and sympathetic counseling.

In 1938 a continuing grant from Miss Grizzelle M. Norfleet made possible a 12-bed cerebral palsy unit at Duke University. Without additional outside funds, This clinic functioned for seven years, until the scarcity and high cost of personnel made it advisable to suspend the work temporarily. The work done in the Norfleet project stimulated wide interest, which resulted in the General Assembly of the State of North Carolina creating Bill SB178 to establish and construct on

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From the North Carolina Cerebral Palsy Hospital, and the Orthopaedic Division of the Department of Surgery, Duke University School of Medicine.

the Duke University campus the 40-bed state-supported North Carolina Cerebral Palsy Hospital. The purpose of the hospital is to provide treatment and educational opportunities for mentally normal children, diagnosed as having cerebral palsy. The first in-patient was admitted on Feb. 20, 1950.

There have been 741 patients processed through the diagnostic clinic. Of these, 251 have been deemed treatable, either in the home, in the outpatient clinic, or in the hospital. Of the 251 patients, 166 have been admitted for treatment and 33 are on the admission list. In some instances admission has been only for observation and better evaluation of the physical and/or the mental status of the patient. In a few of the remaining 52 deemed treatable, the affliction is too minor to warrant in-patient therapy. In the others, home therapy programs have been instituted, not with any expectation of appreciable improvement but to avoid despair until sound and sympathetic counseling can reveal the truth.

TABLE 1.—*Operations*

Dates	Patients	Operations	Totals	
			Patients	Operations
1950				
Feb.-June	1	1	..	..
July-Dec.	3	7	4	8
1951				
July-June	12	42	..	..
July-Dec.	10	22	22	64
1952				
Jan.-June	27	86	..	..
July-Dec.	44	135	71	221
1953				
Jan.-May	21	71	21	71
Grand total			118	364

SURGERY IN CEREBRAL PALSY

During the early days of the hospital, little or no surgery was attempted. As time went on, the results from the so-called conservative treatment were observed and questioned. Perhaps one of Wilson Mizner's aphorisms, "I respect faith but doubt it is what gets you and education," best describes our attitude toward the nonsurgical program. In spite of statements to the contrary, it was proved that many patients with cerebral palsy problems can be best treated by early surgery followed by rehabilitation training, rather than waiting for failure in the latter before resorting to surgical correction. It was also realized somewhat gradually that the benefits derived from surgery should not necessarily be limited to the spastics. Hearsay word-of-mouth teaching and a "laissez-faire" attitude has established the rule, "never do surgery in the athetoid." The rule is well founded if it refers to the athetosis, but not to recognize the benefits that can be gained by elimination of tension and its resultant overflow and deformities in the tension athetoid is in error as much as not to recognize and eliminate similar deformities in the poliomyelitic or spastic patient. The benefits gained by tenotomies and neurectomies to reduce

tension in the severe tension athetoid are not confined only to the parts operated on, but with the elimination of local tension and the resultant overflow widespread improvement may occur.

The purposes of this paper do not include a discussion of the over-all surgical problem in cerebral palsy, but a statistical report can illustrate the change in attitude toward surgery during the past three years at the North Carolina Cerebral Palsy Hospital. From February, 1950, to July, 1950, one patient had one surgical procedure; from July, 1950, to January, 1951, three patients had seven surgical pro-

TABLE 2.—*Types of Operations*

Neurectomies		117
Obturator	82	
Gastrocnemius	20	
Soleus	15	
Tenotomies		152
Adductors	78	
Achilles	37	
Hamstrings	29	
Iliotibial	5	
Gastrocnemius	2	
Posterior tibial	1	
Muscle releases		51
Gastrocnemius	40	
Tensor fascia	5	
Hip flexors	5	
Durham operation	1	
Tendon transplants		22
Wrist and hand	10	
Anterior tibial	5	
Pronator teres	3	
Patella	4	
Fusions		13
Wrist	3	
Hoke	6	
Miller	2	
M. P. Joint	2	
Tarsal blocks		4
(Green)	4	
Osteotomies		5
Femur	3	
Tibia	2	
		364

cedures—a total of four patients with eight operations in an 11-month period. From January, 1951, to July, 1951, there were 12 patients who had 42 operative procedures; from July, 1951, to January, 1952, there were 10 patients who underwent 22 procedures; a total of 22 patients with 64 operations in 1951. From January, 1952, to July, 1952, there were 27 patients who had 86 procedures. From July, 1952, to December, 1952, there were 44 patients who had 135 procedures, a total of 71 patients with 221 procedures. From January, 1953, to May, 1953, there were 21 patients who had 71 procedures, a grand total of 118 patients with 364 procedures.

In general, the results of the surgery have been satisfactory. In many instances they have been beyond expectations. In all the patients the physical therapy pro-

gram has been aided. The greatest general improvement has been in the severe tension athetoid in whom extensive myotomies, tenotomies, and neurectomies have been carried out, usually at one sitting and in the lower extremities. In these patients the release of tension and the lessening of the athetosis in the upper extremities has been surprising. It is felt that the general improvement can be attributed to the moderation of overflow from the lower extremities.

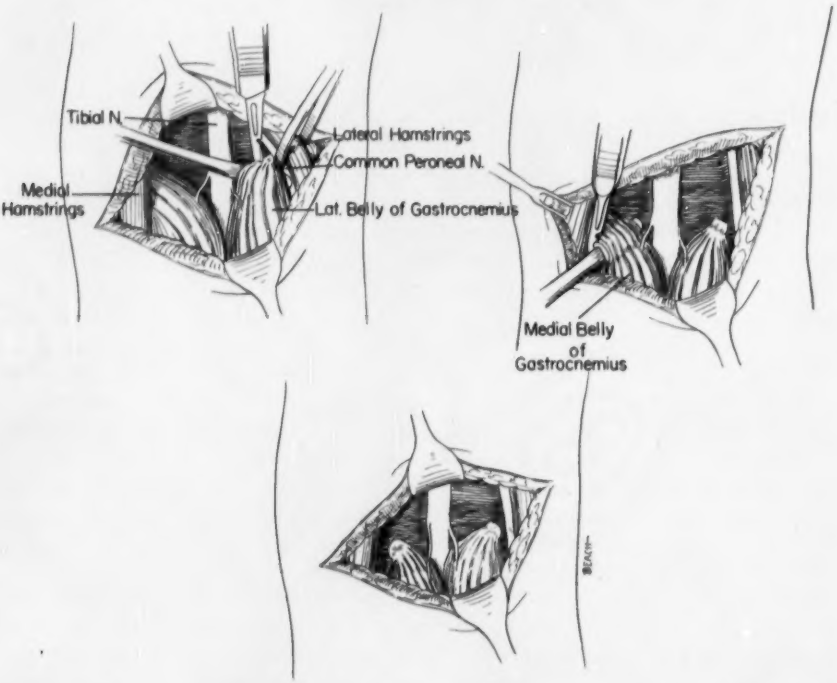
The commonest, and one of the most difficult, surgical problems in the cerebral palsied is to obtain adequate relief without overcorrection of gastrocnemius and soleus involvement. These muscles, which form the triceps surae, are frequently involved in the cerebral palsy patient with spasticity and in the patient with severe tension associated with athetosis. The disorders may be simple or may represent one or more of several combinations: It may represent primary spasticity or primary tension within the muscle. The entangled function may be caused by one or all components of the muscle being agitated by one or more stimuli. It may be compensatory in response to disturbance elsewhere in the antigravity muscles, or it may be evidence of severe overflow stimulated in other parts of the body or extremities. In addition, actual shortening can occur in the muscle bellies or in their tendons. Such shortening is likely to be the result of long-standing improper positioning rather than of spasticity or tension per se.

All the various theories and complications associated with the dysfunctions that are possible in the triceps surae muscle in the cerebral palsy patient cannot be fully covered in this discussion. The aims of surgery may include as their goal one or a combination of any or all of the following: decrease in spasticity; elimination of clonus; restoration of functional or anatomical length; decrease or control of overflow to the muscles; decrease of overflow from the muscles; correction of equinus; restoration of knee extension; correction of eversion or inversion of the os calcis; correction of pes planus, and/or release of tension.

Once it is determined that an overactive triceps surae needs surgical correction, a complete appraisal must be made of the muscle, of its component parts, and of its intrinsic actions before deciding as to the procedure of choice. The decision will rest between neurectomies, tendon lengthening, or transplant. If with the knee extended, it is possible, even by extreme force, to fully dorsiflex the ankle, one should not lengthen the achilles tendon. Doing so will only allow the spastic or tense muscle bellies to contract further and their excursion to lessen. If with the knee flexed the ankle can be fully dorsiflexed with ease, neurectomy, especially of the soleus may weaken an already weak, although spastic, muscle. A good rule that need not be hard and fast is to neurectimize only when disabling clonus is present, and even then the neurectomy should include only the nerve branches to the bundles of muscle that show clonic action.[2] When disorder in the triceps surae results in an equinus of the ankle which with the knee flexed can be corrected with minimal force but cannot be corrected with the knee extended, the patient usually walks on the toes with the knees and hips flexed. The hip and knee flexion may be the result of spasticity or tension in other antigravity muscles. However, if with the foot in equinus the knee can be passively extended easily, the hamstrings are probably not too involved and the gastrocnemius is probably at fault. In such patients a release of the origin of the gastrocnemius muscle bellies and their tendons has been employed and found to be most beneficial in restoring better posture and function without serious loss of power for knee flexion or ankle extension.

OPERATIVE TECHNIQUE

The operation can be best carried out through a hockey-stick transverse incision across the lower portion of the popliteal space, the superficial nerves being preserved and folowed to their origin from the posterior tibial. The proximal portion of the origins of the two heads of the gastrocnemius are easily identified, as is the peroneal nerve and the hamstring tendons. The procedure is not difficult. In carrying it out, one must be certain that the exposure extends far enough medially and laterally to allow release of the medial and lateral expansions of the muscle which pass around well anteriorly to form tendons of origin. Green and Mc-



Upper left, contents of popliteal space exposed. Common peroneal nerve and lateral hamstring tendon retracted. Tendon of origin of lateral belly of gastrocnemius elevated with blunt dissector preparatory to release. Right, same procedure to medial head of gastrocnemius. Lower, origins of gastrocnemius released.

Dermott [8] in describing division of the iliotibial band in conjunction with lengthening of the hamstrings, recommended the division of these tendinous origins of both heads of the gastrocnemius. Exposure of these tendinous origins of the muscle, especially of the lateral head, can be facilitated by retracting the hamstring tendons in toward the popliteal space. This approach to the lateral head avoids unnecessary traction on the peroneal nerve. Sharp dissection is necessary only to incise the strong tendinous bands of origin that lie medially and laterally. The muscular origin from the posterior aspect of the femur and from the capsule of the knee joint, in the main, can be bluntly reflected with the handle of a scalpel. After surgery

long leg casts are applied with the knee fully extended and the ankle in as much dorsiflexion as can be obtained without endangering circulation. The operation serves a threefold purpose: It allows correction of limited dorsiflexion at the ankle, in many instances cuts down on clonus, and, most important of all, allows extension of the knee with the ankle dorsiflexed, which, in turn, can lead to correction of compensatory deformities elsewhere, such as in the hip and spine. It is of interest to theorize as to why this procedure should give such satisfactory correction of the three mentioned factors. Undoubtedly, the elimination of the effects of extension of the knee on the muscle has in part eliminated stretch reflex which, in turn, has lessened the clonus with decrease in overflow. Lengthening of the gastrocnemius portion of the Achilles tendon by the Vulpius method.[4] Although satisfactory when lengthening only is indicated, has not been as effective in eliminating clonus, spasticity, and overflow as has release of the gastrocnemius heads.

SUMMARY AND CONCLUSIONS

During the past decade or more, overemphasis on so-called conservative therapy for the cerebral palsy patient has overshadowed the benefits derived from numerous surgical procedures. A reevaluation of the over-all therapy and a reawakening to the benefits to be derived from surgery are needed. When indicated in the properly selected patient, recession of the heads of the gastrocnemius portion of the triceps surae muscle will allow dorsiflexion of the ankle, will cut down on clonus, and will allow extension of the knee with the ankle dorsiflexed. The procedure should be given due consideration before one attempts an Achilles' lengthening or neurectomy to one of the components of the triceps surae muscle.

REFERENCES

1. McCarroll, H. R.: Surgical Treatment of Spastic Paralysis, in The American Academy of Orthopaedic Surgeons Instructional Course Lectures, Vol. 6, Ann Arbor, Edwards Bros., Inc., 1949, pp. 134-151.

2. Phelps, W. M.: Treatment of Paralytic Disorders Exclusive of Poliomyelitis, in Bancroft, F. W., and Murray, C. R.: Surgical Treatment of the Motor-Skeletal System, Philadelphia, J. B. Lippincott Company, 1945, Vol. I.

3. Green, W. T., and McDermott, L. J.: Operative Treatment of Cerebral Palsy of Spastic Type, J. A. M. A. **118**:434-440, 1942.

4. Vulpius, O., and Stöffel, A.: Orthopädische Operationslehre, Ed. 2, Stuttgart, Ferdinand Enke, 1920.

ENDARTERECTOMY FOR PERIPHERAL ARTERIOSCLEROSIS

G. M. BOGARDUS, M.D.
SEATTLE
CAPTAIN FRANCESCO F. BERETTA
MEDICAL CORPS, UNITED STATES ARMY
REX L. HUFF, M.D.
AND
J. THOMAS PAYNE, M.D.
SEATTLE

IN THIS paper we propose to review some of our experiences with peripheral arteriosclerosis and to comment on endarterectomy in particular. Burt, Learmonth, and Richards [1] quote an earlier description of aortic occlusion given in 1914 by Robert Graham, of Glasgow. The condition was recognized and described by others also, notably Severinus (1632) and Fantanus (1679). In 1894 Severenau broke up a thrombus through the orifice of a main obliterated artery and then was able to amputate at the site of election rather than through the thigh.

Lejars * performed disobliteration through arteriotomies in 1902. Delbet * stated in 1911 that

> the easiest operation that can be done to cure arterial obstruction is incision of the artery, extraction of the thrombus, and closure of the vessel—in thrombosis due to endarteritis one can hope for but little from visualization of the artery. On the impaired walls the clot reforms with a distressing rapidity.

Dos Santos renewed interest in the application of endarterectomy, clearing out the thickened intima and restoring flow through the intimectomized vessel. He emphasized the role of heparin locally at surgery and postoperatively to lessen the hazard of thrombosis. Dos Santos used several transverse incisions. Reboul and Laubry [2] suggested using a longitudinal incision over the length of the obstructed segment. Leriche felt that the procedure was reasonable and an improvement over the previous indirect form of therapy. In this country Wylie, Kerr, and Davies have reported a number of endarterectomies; they advocate wrapping the remaining media with fascia to lessen the hazard of aneurysm of rupture. Freeman and Gilfillin [4] have described the use of intra-arterial heparin to provide a high local concentration of heparin, lessening the danger of wound bleeding. Julian, Dye, and Olivier [5] review the subject of the direct surgery of arteriosclerosis, with venous grafts being used in several cases. They performed endarterectomy in six cases. In one case they placed a homograft at the aortic bifurcation. More recently Barker and Cannon [6] reported their experience in 18 endarterectomies.

From the Department of Surgery, University of Washington School of Medicine.

Reviewed by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions of the author are the result of his own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

* Cited by Reboul and Laubry.[2]

PATHOLOGY

A detailed study was made of 93 autopsies, particular attention being paid to the lumbar aorta, the aortic bifurcation, and the iliac arteries. In 28, or 30%, of these cases a fairly typical lesion was found. This lesion consists of arteriosclerotic plaques on the posterior wall of the lower lumbar aorta and of rigid arteriosclerotic plaques localized chiefly on the posteromedial aspect of the proximal portion of the common iliac arteries. The plaques are usually oval in shape, with an average measurement of 3 cm. in length and 1.5 cm. in width, and varying in thickness from 0.1 cm. to complete occlusion of the lumen (Fig. 1). Calcification within the plaques is frequently present and of variable degree. The anterior and lateral aspects of the vessels are involved as well in the more extreme cases. The contrast between this

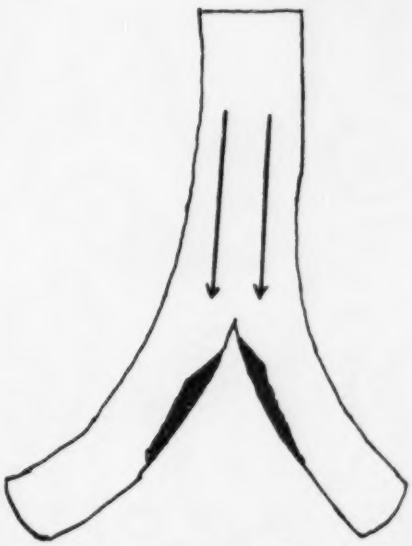


Fig. 1.—Sketch illustrating what often appears to be the area of initial involvement in arteriosclerosis of the iliac arteries. The relation to impact of the aortic arterial jet seems obvious.

involved medial and the less involved lateral portion often is striking. It may be that the impact of aortic jet, chiefly on the medial wall, accounts in part for the early and more marked involvement in this area. Why some vessels are occluded all the way to the inguinal ligament, however, remains unexplained.

The nontypical cases showed variations from little or no involvement to extreme atheromatous degeneration with clot formation, hemorrhages, and multiple splitting of the vessel wall. A striking finding, grossly, is the presence of tissues of soft, pliable, and essentially normal femoral artery, distal to complete iliac occlusion. Moreover, though the orifices of the branching vessels may be occluded, as often as not the occlusion may stop short of the next collateral. Here there need not be thrombosis, and, moreover, such an area makes it possible to perform the intimectomy while flow is permitted through the collateral channel.

Representative microsections from a number of the aortas described grossly show a corresponding variation in the microscopic changes. These range from a

Fig. 2.—Showing eccentric location of the greatly thickened intima and indicating the slight involvement of the media, part of which is included in the "sequestrectomy."

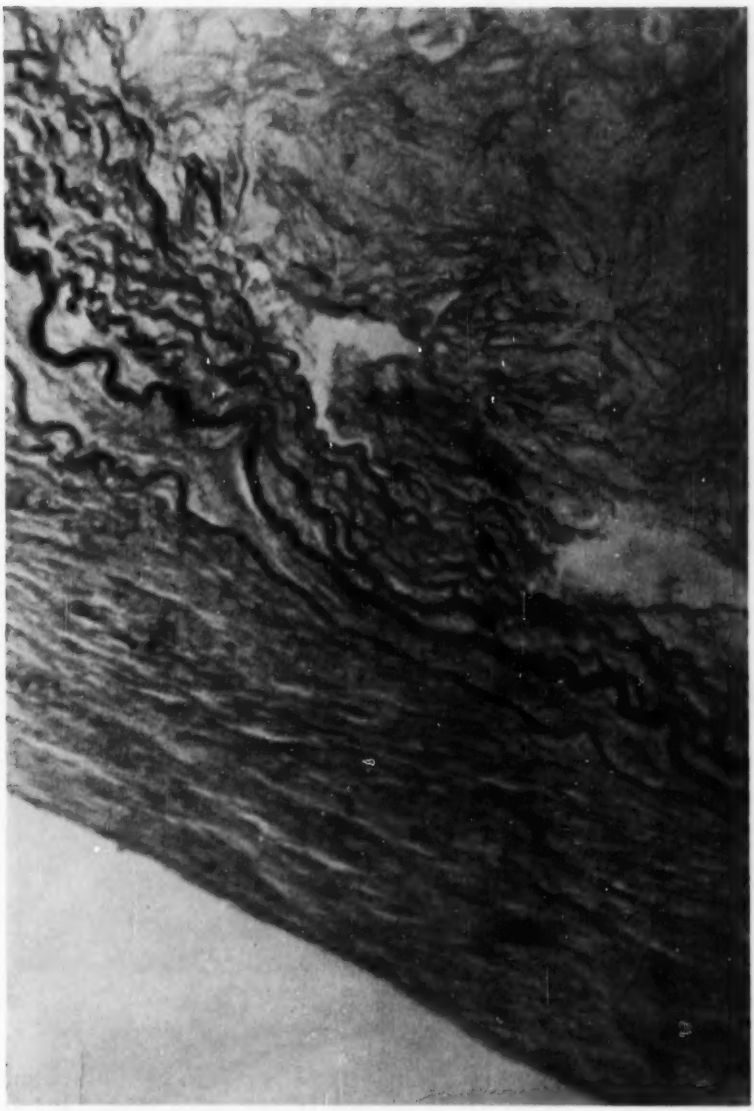


Fig. 3.—Higher power magnification of Figure 2, showing the reduplication of the elastica and the character of the media and intima.

minimal thickening of the wall consisting of some proliferation of the intima to a very pronounced disease with marked thickening of the walls and complete alteration of the normal architectural pattern.

In areas showing extensive disease there is a marked alteration of the normal architecture of the arterial wall. The greatly thickened intima is composed in large measure of the same amorphous material, previously described, and in addition to cholesterol slits, there are foci of calcification. The media is irregular, being thinned

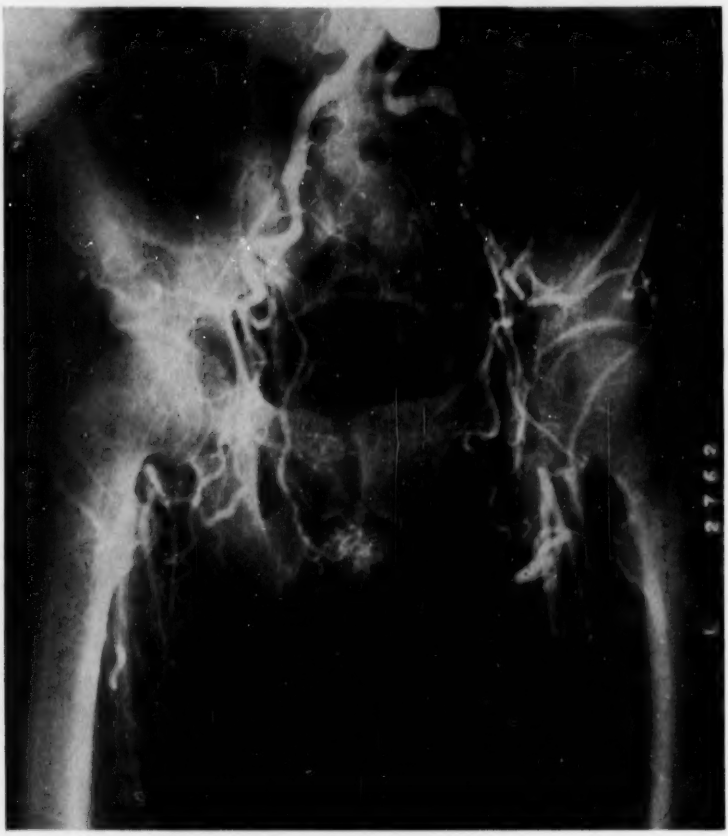


Fig. 4.—Roentgenogram of patient with occlusion of both external iliac arteries. Patient has sufficient collateral circulation to do light work.

and scattered in many sites. The adventitia shows the changes previously mentioned with varying amounts of chronic inflammatory cell infiltration (Figs. 2 and 3).

Some of the sections, in addition to showing very marked intimal and medial disease, are seen to contain thrombi within their lumen. For the most part these are unorganized and consist of masses of red blood cells and fibrin. In the periphery adjacent to the altered intima the thrombi are in some places made up of an amorphous eosinophilic material, but they do not show much organization.

Fig. 5.—Occlusion of the left common iliac artery is demonstrated in this translumbar aortogram, performed for us by Dr. Wylie. Removal of the thickened intima was accomplished with a good result.

In areas where there is maximum involvement the remaining aortic wall consists of only a very broad zone of unorganized thrombotic material overlying greatly thickened and scarred intima in which there are all of the changes enumerated previously. The intima covers a hardly recognizable media which is thinned and atrophic. Prominent inflammatory cell infiltration of a chronic nature is seen in the adventitia.

SYMPTOMATOLOGY AND PHYSICAL FINDINGS

A few words should be said about the symptoms and signs of peripheral arteriosclerosis. The level of occlusion and the extent of collateral circulation are important

Fig. 6.—Retrograde injection arteriogram reveals a block almost at the origin of the left common iliac artery.

items in this regard. Leriche has ably described the syndrome of obliteration at the lower end of the aorta, with its attendant picture of weakness in the limbs, claudication, and, in the male, impotence. With iliac artery occlusion the symptoms may be centered around the gluteal muscles and the thigh, with weakness, atrophy, and pain in that area. Disease of the lumbar spine or hip may be simulated. An important finding in iliac artery occlusion is the history of claudication, worse on one side, with perhaps some atrophy, and most of all an absent or weak femoral pulse on the involved side with a good pulse in the femoral artery of the opposite side. A systolic murmur may be found when there is stenosis, but no complete occlusion. Another important point is that segmented occlusion need not be associated with gangrene.

Gangrene is more likely to be found with diffuse peripheral obstruction or segmental occlusion of smaller end arteries of certain muscles or skin area, e. g., in the arteries of the calf and the foot. Edwards [7] recently called attention to the anatomic basis of localized ischemia in the extremity.

INDICATIONS FOR INTIMECTOMY

Direct surgical attack on an obstructed arterial segment is indicated in patients who present persistent symptoms of localized arterial insufficiency. The diseased

Fig. 7.—Example of aortography performed at the time of surgery, under direct vision.

vessel should be of sufficiently large caliber; the obstruction should not be of great length, and, of course, the patient should not present any contraindication to surgery. It is true that in many patients adequate collateral circulation will develop to make operation unnecessary. An example of this is seen in Figure 4. This patient is able to carry on his work satisfactorily although both external iliac arteries are occluded. This patient has had a lumbar sympathectomy on the left side only.

The usual conservative measures and safeguards indicated in the care of diabetics with arterial disease are applicable to the care of patients with peripheral arteriosclerosis without diabetes. Careful foot hygiene is indispensible. In certain cases lumbar sympathectomy will give sufficient relief of pain to be worth while.

X-RAY STUDIES

Just as bronchograms are necessary for accurate visualization in bronchiectasis, so are arteriograms useful in the study of peripheral arterial disease. When obstruction appears to be present at the bifurcation of the aorta, translumbar arteriography is applicable (Fig. 5). The site of block in the left common iliac artery is well visualized. This occlusion was removed satisfactorily, and the postoperative course was satisfactory. Several of our patients have shown unilateral occlusion, with the opposite femoral artery having a good flow. In some of these patients we have done retrograde injection through the good side by catheter threaded through a needle. At times we have done retrograde injection on the diseased side to show the area of block (Fig. 6). In unilateral occlusion we have tended to perform arteriograms at the time of operation. Exposure is obtained with the use of an oblique flank

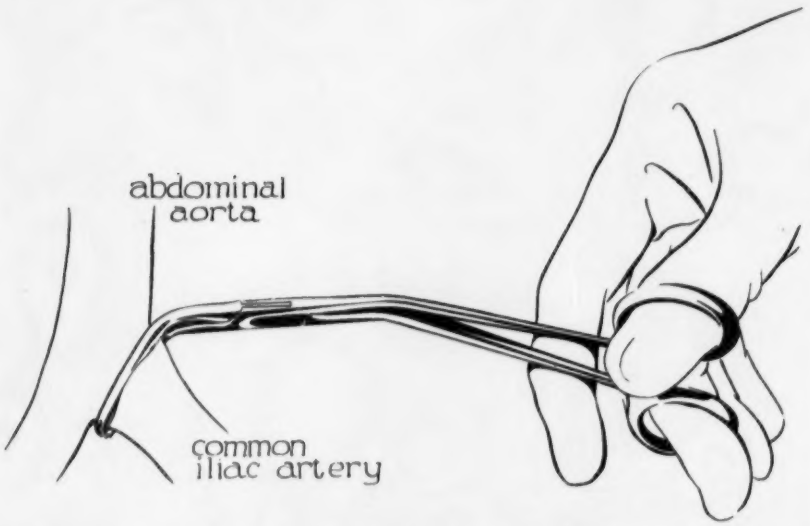


Fig. 8.—Use of the angled clamp, as illustrated, may permit flow to continue through the opposite uninvolved vessel.

incision, the aorta and iliac vessels being approached extraperitoneally. A needle is then placed in the aorta or iliac artery proximal to the block; 30 cc. of 70% of iodopyracet (Diodrast) injected, and the picture taken with use of the Bucky technique. An example of this technique is seen in Figure 7.

OPERATIVE TECHNIQUE

Exposure of the iliac vessels and the lower aorta may be obtained either through a long midline incision or a long oblique incision. With the oblique incision the vessels are approached extraperitoneally, and this has advantages in simplicity of exposure as well as in improved postoperative recovery. When the block is unilateral, the extraperitoneal approach is favored. In either case, one should avoid damage to the inferior epigastric artery, which may be serving a useful function as a collateral. Once exposure has been obtained, the artery is gently separated from the

Fig. 9.—Hovnanian's incision for groin dissection, with use of osteotomy of the superior iliac spine, provides good exposure of the lower iliac and proximal femoral vessels.

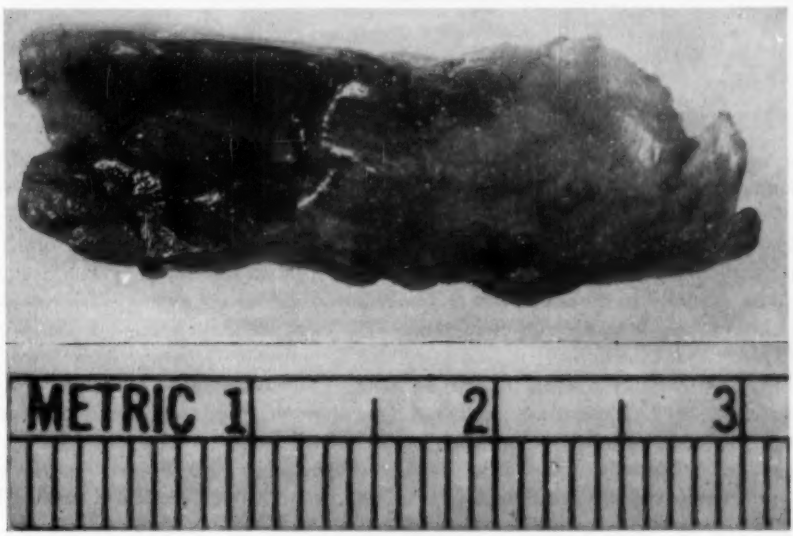


Fig. 10.—Example of one of the surgical specimens removed intact. Often it is necessary to make multiple incisions and to remove the diseased portions in fragments.

adjacent vein. Proximal control of the common iliac artery is facilitated by using an angled Potts ductus clamp, as illustrated (Fig. 8). Use of this clamp permits active flow through the opposite iliac artery at all times. By placing the distal clamp proximal to the site of collateral flow, there will be no interruption of blood flow to the extremity at any time. Access to the distal portion of the external iliac artery and the proximal portion of the femoral artery may be had by using Hovnanian's method of reflecting the inguinal ligament after osteotomy of the anterior superior iliac spine (Fig. 9).

After a longitudinal incision is made over the obstructed area, the diseased intima will be found to separate readily. At times a small portion of media will be included in the specimen. A Sachs nerve dissector is useful to work along the line of cleavage. As much intima is removed as is necessary to restore good flow, both distally and proximally. At times separate transverse incisions may be more suitable. In these cases, one may carefully work the dissector from one transverse incision to

Patients Treated by Endarterectomy

Case	Site of Block	Procedure	Result
1	Left common iliac artery	Endarterectomy	Temporary improvement
2	Left common iliac artery	Endarterectomy	Poor
3	Left common iliac artery	Endarterectomy	Good
4	Left external iliac artery	Endarterectomy	Fair
5	Abdominal aorta	Endarterectomy	Good
6	External iliac artery	Endarterectomy, sympathectomy	Poor
7	Left common and external iliac artery	Endarterectomy	Poor
8	Right common femoral artery	Endarterectomy	Technically satisfactory but too recent to evaluate

the next and then extract the thickened intima. During this maneuver it will be found that there is considerable mobility of the remaining media, which may be rolled back, displaying the underlying intima. The opened vessel is flushed with heparin solution, 200 mg. per 1,000 cc. and the media approximated with a running over-and-over atraumatic 00000 nonabsorbable surgical (silk) suture. The incision is then carefully compressed with a laparotomy pad, and both clamps are released quickly to provide immediate rapid flow. Slow removal of the clamps or removing one clamp at a time is likely to lead to sudden thrombosis. Gentle pressure is maintained on the suture line for 10 minutes, and, if any bleeding persists, interrupted sutures are used. Sympathectomy is not done; however, probably some sympathectomy effect is obtained during mobilization of the vessels by periarterial sympathectomy. Heparin is not being used now postoperatively. Figure 10 shows a specimen removed at operation. Figures 2 and 3 are a cross section of one of the surgical specimens, showing the diseased intima and a small portion of media.

REPORT OF CASES

A brief summary of our eight cases is shown in the Table. A more detailed individual case report follows.

CASE 1.—E. I. S., Reg. No. 6,738, 62-year-old white married man, had intermittent claudication for the past year, most marked in the left leg and thigh, occurring after walking for a block and a half. The pain was relieved by resting. Physical examination revealed a 2+ femoral pulse and a palpable right posterior tibial pulse. The left femoral pulse was only questionably present. The left posterior tibial pulse was absent. A retrograde arteriogram showed a block in the proximal portion of the left common iliac artery. On Feb. 5, 1953, an endarterectomy of the left common iliac artery was performed through a left paramedian incision. Postoperatively the patient was treated with heparin. Convalescence was uneventful. The patient's symptoms were greatly improved, and he could walk many blocks without claudication. A left femoral pulse was weak, but present; the posterior tibial pulse could not be made out. March 18—absent left pulse, femoral posterior tibial; claudication had returned. The left femoral and posterior tibial pulsations were absent and claudication had returned.

Comment.—This patient had only partial removal of intima from around the ostium of the common iliac artery. Better control of the aorta would have permitted access to this area and led to a better result.

CASE 2.—R. D., Reg. No. 7,376, 62-year-old white married man, noted numbness of the sole of the left foot six months prior to admission, followed in two months by pain over the posterior aspect of the left hip after walking one-half block. He also had aching of the calves, relieved by resting. The right femoral and posterior tibial pulsations were palpable, but the left femoral and left posterior tibial pulsations were absent. At operation on Aug. 15, 1952, an aortogram showed a block in the left common iliac artery; endarterectomy of the left common iliac was performed. Heparin was not used postoperatively. Postoperatively a rather good left femoral and posterior tibial pulse was obtained. March 25, 1953—a femoral pulse was palpable on the right but not on the left. He still had claudication on the left thigh and hip after one-half block. May 6, 1953—a right femoral and posterior tibial palpable; left femoral and posterior tibial not palpable.

Comment.—Here again, proper access was not had to the ostium of the iliac artery. In this case the result should have been better, with complete cleaning out of the iliac arteries.

CASE 3.—E. G. J., Reg. No. 6,163, 54-year-old white man, for several months had weakness in the left leg and absent left femoral pulse, with claudication occurring after one and a half blocks. The aortic pulse was 4+, right iliac, femoral, and popliteal 4+, and 4+ posterior tibial pulse. Pulse was absent from left iliac distally. A translumbar anteriogram showed block at the left iliac and narrowing in the right iliac. Left thromboendarterectomy was done on Sept. 18, 1952, through an extraperitoneal approach, with good results. Six months later he still had a left femoral and posterior tibial pulse with much symptomatic relief in left leg.

Comment.—This patient had a fairly satisfactory result and was the first to have a really satisfactory intimectomy.

CASE 4.—W. G., Reg. No. 5,020, 60-year-old man, was admitted because of intermittent claudication of the lower extremities for seven years and incipient gangrene of the left foot. He had a left lumbar sympathectomy in February, 1952, without relief. He had been unable to walk more than a block without resting. Physical examination revealed a right femoral pulse but no right posterior tibial pulse and no pulsations in the left leg. An arteriogram showed a block in the external iliac artery. Endarterectomy on Oct. 15, was performed through an extraperitoneal approach. Postoperatively, the patient had a good left femoral and posterior tibial pulse. Heparinization was not used postoperatively. March 18, 1953—a good left femoral and posterior tibial pulse; still has ulcer, but no progression of disease.

Comment.—This patient had extensive disease with ulceration of the foot when first seen. It was felt that he was not a good candidate, but since he had a segmental block, the block was removed in an attempt to forestall further deterioration. Though symptoms have not been relieved, it is believed that progressive gangrene was averted.

CASE 5.—G. D., Reg. No. 6,009, 60-year-old white man, with history of 12 years of pain in both legs. Peripheral arterial pulsations were absent in both lower limbs. A left lumbar sympathectomy was performed on Jan. 12, 1953, with slight improvement. On Feb. 4, a left thigh Callander amputation was performed with resultant slow healing. On Feb. 26 the patient had a sudden bout of severe pain in right leg and discoloration of lower abdomen. Immediate transperitoneal exploration of the aorta was done, with removal of a large calcified plaque obstructing the vessel just below the superior mesenteric artery. Convalescence was uneventful except for reamputation of the left thigh.

The patient returned on May 25, with cramps in the left thigh stump and rather impaired circulation in the right leg and thigh. There now is pallor on elevation of the right leg, marked rubor on dependency, and still absent femoral, popliteal, and posterior tibial pulse.

Comment.—This patient was saved from a catastrophic vascular occlusion by aortic endarterectomy. He still has impaired peripheral circulation, however, and the ultimate outlook is poor.

CASE 6.—H. D., Reg. No. 8186, 58-year-old white man, had been a known diabetic since the age of 30. He had had a sympathectomy and later an amputation of the left leg for arteriosclerotic disease. Since March, 1953, he had had marked pain in the left leg and persistent ulceration of the foot. He had a faint right femoral pulse with a bruit. Arteriogram showed marked narrowing of the iliac artery. Both external iliac endarterectomy and sympathectomy were performed on July 20. Postoperatively he has had a much better femoral pulse. Pain in the leg and hip persist, however.

Comment.—Postoperatively, pain persisted in the hip and pelvis, while there was some temporary improvement in the leg pain. Evidence of impaired circulation persisted however, such that amputation was required. The amputation was performed as a high below-knee operation because of the previous amputation on the left. At present there is a small patch of necrosis of the anterior flap, which, it is hoped, will eventually heal.

CASE 7.—T. K., Reg. No. 5903, 55-year-old white man, had had a left lumbar sympathectomy because of a chronic leg ulcer due to arterial insufficiency. Aortogram at the time of the sympathectomy showed diffuse narrowing of the common iliac artery and the external iliac artery. It was felt that intimectomy would not be practicable in this case. However, after many months of observation and treatment, progression of the ulcer seemed to warrant an attempt at endarterectomy. An arteriogram of the femoral artery showed a normal pattern on Aug. 10, 1953. An endarterectomy of the left common and external iliac artery was performed, and clot was also removed from the proximal portion of the femoral artery. After this procedure, fairly good flow was obtained; however, at operation the femoral artery was quite narrowed. The improvement subjectively was only temporary; consequently, subsequent thigh amputation was required. At amputation, no flow was obtained from the opened distal femoral artery.

Comment.—The condition of the patient in the case was far-advanced and not really suitable for endarterectomy. Possibly an earlier operation, with the use of a long graft, would have been more successful.

CASE 8.—V. W., 62-year-old white man, had been known to have chronic lymphatic leukemia for three years. He previously had had a left lumbar sympathectomy for arterial insufficiency on Dec. 31, 1951, and a right lumbar sympathectomy on Jan. 8. After the sympathectomies there was improvement in the left leg, but pain and claudication progressed on the right.

He was readmitted on Aug. 24, 1953, complaining of being able to walk only one-half block, being forced to stop because of severe pain in the right calf. The pain is relieved after about 10 minutes' rest. Physical examination reveals an elderly white man, 62 years of age. The ulcer is palpable 4 fingerbreadths below the left costal margin. There is moderate pallor on elevation of the lower extremities, with moderate atrophy of the skin and musculature. Each femoral artery has a good pulsation, and no bruit is noted. There is no pulse evident distal to the com-

mon femoral artery. Arteriogram of the right femoral artery showed complete failure of filling of the superficial femoral artery. The common femoral artery was well filled and showed a large profunda and lateral circumflex artery. However, just at the point of origin of these two arteries there was an area of almost complete occlusion over a distance of about 2 to 3 mm.

At operation the femoral artery was exposed. A dense arteriosclerotic plaque was found in the femoral artery just at the common origin of the profunda and lateral circumflex artery. There was fairly good flow through these vessels but no flow in the superficial femoral artery. A thrill was noted in the profunda femoral artery. After mobilization of the vessels, a longitudinal incision 1 in. (2.5 cm.) long was made in the common femoral artery, through which occluding intima and thrombus were removed from around the orifice of the profunda femoral artery. After closure with 00000 arterial silk, there was improved flow in the profunda and lateral circumflex artery, and the thrill had disappeared.

Comment.—This patient, only recently operated upon, was found to have a completely occluded superficial femoral artery and an extreme narrowing of the ostium of the profound femoral artery. Removal of the thickened intima from around the ostium should result in improved flow and should delay the threat of occlusion of the profunda, the main source of blood supply to the thigh and leg.

COMMENT

The first two patients had admittedly incomplete endarterectomies around the origin of the common iliac artery. Since modification of the Potts ductus clamp, this has been easier to deal with. The bent clamp can be placed high enough on the aorta to provide access to the ostium of the common iliac artery, yet flow can continue through the aorta into the opposite iliac channel. If this is not possible, the aorta should be controlled and adequately opened, as described by Wylie. We feel that the procedure of endarterectomy is a feasible and an appropriate form of therapy in a small percentage of patients suffering from occlusive arteriosclerotic peripheral vascular disease. In these patients the procedure is essentially an intimectomy of thickened, sclerotic, and even calcified intima. Thrombosis is not a primary feature of the disease process. If the procedure has been technically adequate, subsequent thrombosis is not inevitable. In two of the patients thought to have had an adequate intimectomy, posterior tibial pulsation has persisted from six to nine months. That the procedure is applicable high on the abdominal aorta is shown by the successful removal of diseased intima from one patient.

SUMMARY

The background of endarterectomy for occlusive arteriosclerotic disease has been briefly reviewed. Our studies of the surgical material and autopsy findings in peripheral arteriosclerosis have suggested that there may be localized points of constriction in major vessels which can be relieved by surgical removal. This removal, or endarterectomy, can be done satisfactorily in certain selected cases without undue risk to life or limb. An extraperitoneal approach to the constricted endopelvic arteries has been satisfactory. This concept of endarterectomy for arteriosclerotic peripheral vascular disease has been applied to patients with encouraging results.

REFERENCES

1. Burt, C. C.; Learmonth, J., and Richards, R. L.: On Occlusion of the Abdominal Aorta: Part III, Aortic Embolism, Edinburg M. J. **59**:113, 1952.

2. Reboul, H., and Laubry, P.: Endarterectomy in the Treatment of Chronic Endarteritis Obliterans of the Limbs and Abdominal Aorta, Proc. Roy. Soc. Med. **43**:547, 1950.

3. Wylie, E. J.; Kerr, E., and Davies, O.: Experimental and Clinical Experiences with the Use of Fascia Lata Applied as a Graft about Major Arteries After Thrombo-Endarterectomy and Aneurysmorrhaphy, Surg., Gynec., & Obst. **93**:257, 1951.

4. Freeman, N. E., and Gilfillin, R. S.: Regional Heparinization after Thrombo-Endarterectomy in the Treatment of Obliteration Arterial Disease: A Preliminary Report Based on 12 Cases, Surgery **31**:115, 1952.

5. Julian, O. C.; Dye, W. S., and Oliver, J.: Direct Surgery of Arteriosclerosis, Ann. Surg. **136**:459, 1952.

6. Barker, W. F., and Cannon, J. A.: An Evaluation of Endarterectomy, A. M. A. Arch. Surg. **66**:488, 1953.

7. Edwards, E. A.: The Anatomic Basis for Ischemia Localized to Certain Muscles of the Lower Limb, Surg., Gynec. & Obst. **93**:87, 1953.

8. Hovanian, A. P.: Radical Ilio-Inguinal Lymphatic Excision, Ann. Surg. **135**:520, 1952.

POLYVINYL INTESTINAL TUBE FOR THE NEWBORN

HERMAN J. SUGARMAN, M.D.
AND
ORVAR SWENSON, M.D.
BOSTON

NO TUBE of proper size, consistency, and length has been available for intestinal intubation of newborn and young infants. In the past only gastric intubation with a No. 8 F. catheter or a No. 10 F. Levin tube was possible. This note presents our experience with an intestinal tube suitable for newborn infants.

The tube described is a modification of the Harris design,* made with a new polyvinyl tubing instead of rubber. It has the consistency of a rubber catheter of equal size, but its thinner wall provides a larger bore. Polyvinyl tubing can be boiled without damage, but autoclaving is impracticable, since it alters the physical properties of the tubing.

Comparison of Sizes of Tubes Commonly Used in Treatment of Intestinal Obstruction in Infants

Tube	Outside Diameter, Mm.	Lumen, Mm.
No. 8 F. Urethral catheter	2.4	1.0
No. 10 F. Levin tube	3.2	1.4
No. 12 F. Miller-Abbott tube	4.0	1.4
No. 8 F. Polyvinyl intestinal tube	2.2	1.5

The accompanying Table illustrates the comparative sizes of the No. 8 F. urethral catheter, No. 10 F. Levin tube, No. 12 F. Miller-Abbott tube, and our No. 8 F. polyvinyl intestinal tube. The No. 8 F. urethral catheter is too short for effective intubation of the small intestine. The No. 12 F. Miller-Abbott tube and our No. 10 F. Levin tube are the smallest-sized rubber tubes long enough for intestinal intubation, but frequently it is impossible, because of their size, to insert them into the nose of a newborn or small infant. The polyvinyl intestinal tube has a slightly smaller external diameter, but its lumen is one and one-half times as large as that of the No. 8 F. urethral catheter. The lumen of our intestinal tube is slightly larger than the bore of the No. 10 F. Levin tube and the No. 12 F. Miller-Abbott tube.

The materials needed for the construction of the tube are few and inexpensive: 3 ft. (0.91 meter) of polyvinyl tubing (size No. 8 F.), a small thin-walled rubber finger cot, 0.5 to 1 cc. of mercury, No. 6-O braided silk, and a No. 15 gauge needle, preferably with a blunted tip.

Senior Assistant Resident in Surgery (Dr. Sugarman) and Surgeon-in-chief (Dr. Swenson), The Boston Floating Hospital for Infants and Children.

* References 1 and 2.

The tube is constructed in the following manner: The tip of the polyvinyl tubing which is to enter the nares is passed with a quick spinning motion through a match flame to round the cut end without constricting the lumen. The finger cot tip is cut across with scissors, making a hole through which the polyvinyl tubing can be forced. The closed end of the finger cot is placed approximately 5 mm. from the flamed end

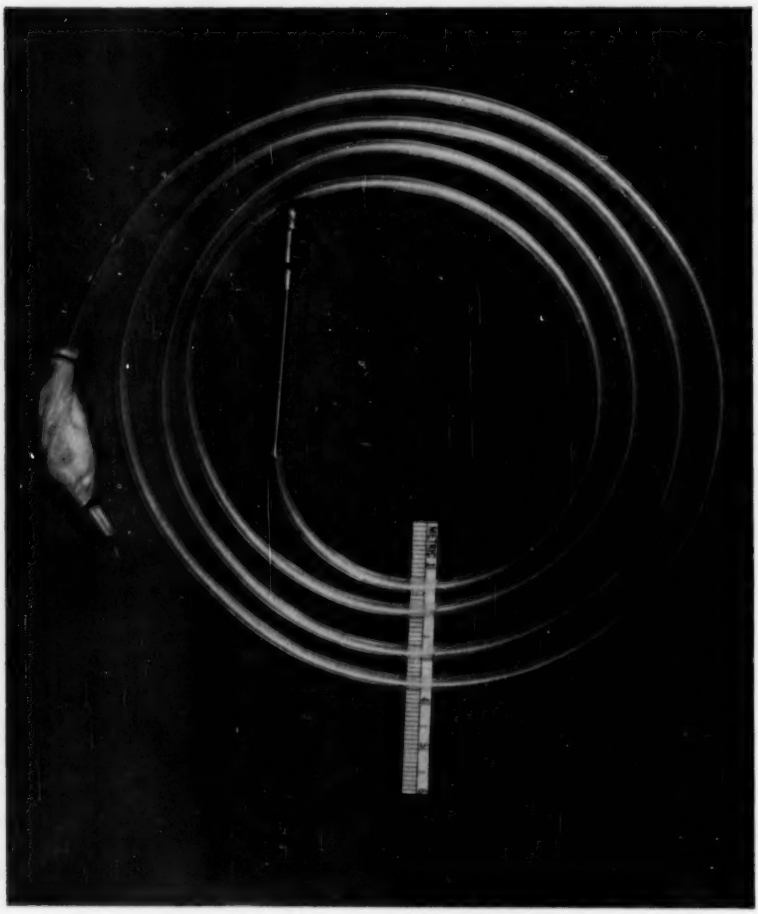


Fig. 1.—The polyvinyl infants' intestinal tube.

of the tube. With an assistant holding the tube and finger cot in position, the closed end of the finger cot is fastened firmly to the tube by numerous turns of No. 6-O braided silk. Five-tenths to 1 cc. of mercury is then placed in the finger cot, which is twisted about the tube to remove the excess air. Numerous turns of 6-O silk are wound about the finger cot 3 cm. from the first ligature and tied, and the excess length of the cot is trimmed. For small perforations, about 2 mm. in diameter, are then made with scissors on the long end of the polyvinyl tube within 4 cm. of the

cot to provide for intestinal drainage proximal to the mercury bag. These perforations are readily made by bending the tube on itself and excising small segments with scissors, taking care that the perforations are no larger than one-third of the circumference of the tube. A No. 15 needle, preferably with a blunted tip and, if possible, with an enlarged bore, is then introduced into the opposite end of the tube.

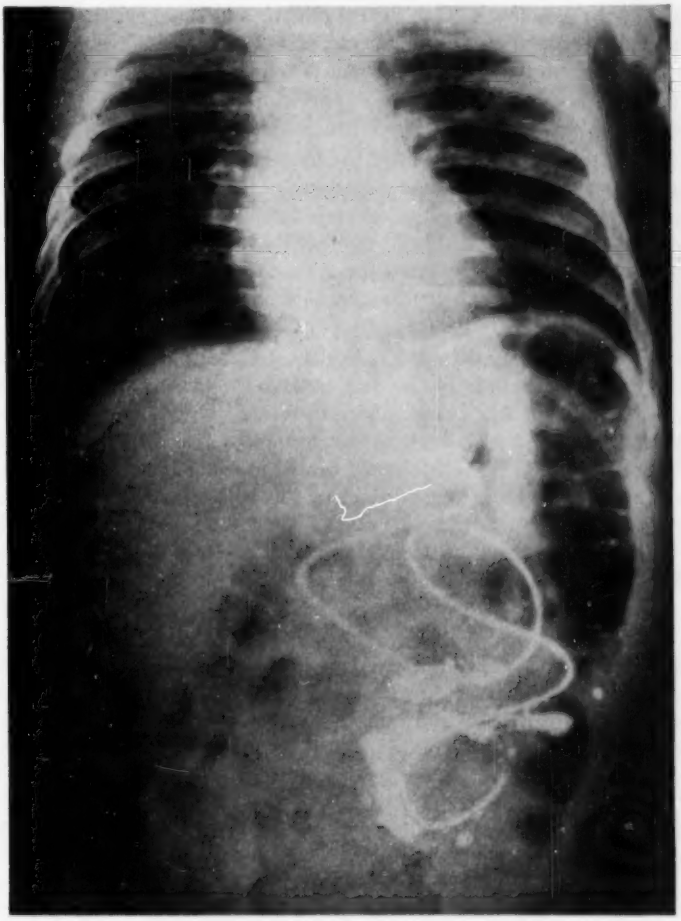


Fig. 2.—Roentgenogram showing intestinal tube in place. Iodized oil, U.S.P. (Lipiodol) has been injected into the tube for better visualization.

The needle may later be connected to the source of suction by any available intravenous needle adaptor.

The following procedure has been found most successful in intubating the small intestine of infants. The tip of the intestinal tube and finger cot are lightly coated with aqueous lubricating jelly. The patient is held in an upright position, and a nipple filled with cotton soaked in a sugar solution is placed in his mouth while the

tube is gently inserted through what appears to be the larger of the two nasal passages. Steady pressure just behind the mercury bag will aid in passing the bag into the nasopharynx. The tube readily descends into the stomach as the infant swallows. The best method for rapid duodenal intubation is to place the infant under a fluoroscope and position the tube so that the mercury bag is at the pylorus with the tip pointing toward the duodenum. Often the tube can be manipulated into the duodenum by the radiologist. If this is not possible, the tubing behind the bag should be positioned along the greater curvature of the stomach. This provides enough slack in the tubing so that no advancement of the tubing from above is necessary to permit the tube to enter the duodenum. The infant is then placed flat in bed on his right side and held in this position by restraints.

During this period the free end of the tube is permitted to hang over the edge of the crib with the needle hub over a receptacle. Excess pressure in the stomach is thus removed without draining the stomach completely. The fluid in the stomach promotes peristaltic activity and helps to move the mercury bag through the pylorus. Furthermore, avoiding suction keeps the gastric mucosa from adhering to the perforations in the tube. Every hour the tube is irrigated with 5 cc. of saline by means of a syringe placed directly on the hub of the No. 15 needle.

When bile-stained material appears in the tube after the initial evacuation of the stomach, a roentgenogram is obtained to confirm the presence of the mercury bag in the duodenum. The bag is easily identified, and the tube itself can be seen on close examination. Should it be desirable to outline the course of the tube more definitely, iodized oil, U.S.P. (Lipiodol) can be injected into it. When the tip has been demonstrated to be in the duodenum, the tube is connected to a source of intermittent suction and advanced 1 in. (2.5 cm.) per hour through the nares. Hourly irrigations of the tube are continued. The infant's position may now be changed, but restraints should be used to keep him from placing traction on the tube.

COMMENT

During the 20 instances in which the infants' intestinal tube has been used, inserting the tube presented no difficulty. Drainage has been excellent. The presence of the tube in the pylorus has not impaired the passage of fluids about it after the tube has been clamped. We believe that the use of this intestinal tube postoperatively has obviated a second operation on several occasions.

The polyvinyl intestinal tube may have a further use in diagnostic duodenal drainage for infants with a concomitant gastric tube to prevent dilution of duodenal fluid by gastric juice.

REFERENCES

1. Harris, F. I.: Intestinal Intubation in Bowel Obstruction, Surg., Gynec. & Obst. **81**:671 (Dec.) 1945.

2. Harris, F. I., and Gordon, M.: Intestinal Intubation in Small Intestinal Obstruction and Distention: Further Experiences with the Single Lumen Mercury Weighted Tube and Analysis of Complications, Surg., Gynec. & Obst. **86**:647 (June) 1948.

NONPERFORATIVE TRAUMA TO ABDOMEN

JOHN C. COTTRELL, M.D.
LONG BEACH, CALIF.

BLUNT nonpenetrating trauma to the abdomen, mild or severe, may eventuate in a serious emergency. Associated injuries, usually fractures, are commonplace. The likelihood of a concealed viscus rupture always presents a challenging problem. The sudden acquisition of such a case initiates a great responsibility, is almost certain to dislocate routine practice, and will demand maximum attendance with repeated observations. In reaching a prompt diagnosis, a preconceived composite picture of the potential lesions should be in a surgeon's mind; to accomplish early treatment an orderly program of complete investigation should immediately be instituted. Delayed therapy rapidly accelerates morbidity and mortality.

Modern motorization makes each of us a potential victim, giving this matter more than academic interest. Motor vehicles lead as the source of injury, as seen from the following tabulation:

Trauma to the Abdomen and Its Contents (Collins[1])

Automobile-pedestrian	26.2%
Automobile-collision	10.2%
Automobile-other	13.2%
Automobile total	49.6%
Train-street car	11.5%
Falls	11.0%
Kicks-blows	8.0%
Motorcycles	5.3%

Aviation accidents are not reported, since the majority are immediately fatal. Since half the traumas producing viscus rupture are automotive in origin, detailed information of this etiology is interesting. Highway violence increases in spite of extending safety vigilance. In 1952 on American highways 37,600 persons were killed and 2,090,000 injured, the worst traffic toll in history.[2] Another 274,080 pedestrians were casualties, which latter record is 8% better than in 1951. There were 415,720 drivers in serious accidents who were under 25 years of age, with young drivers involved in almost 25% of the fatal accidents. Three out of four accidents involved cars traveling in clear weather on dry roads, with 9 out of 10 vehicles in good condition, 80% of which were traveling straight ahead. Saturday, between 5 and 10 o'clock in the evening, was the date and time of most accidents. The average victim of a fatal accident was 36 years of age, and the average pedestrian who was killed was 63 years old. In large metropolitan areas two-thirds of the fatalities are automobile-pedestrian in which the victim is a jaywalker, 55

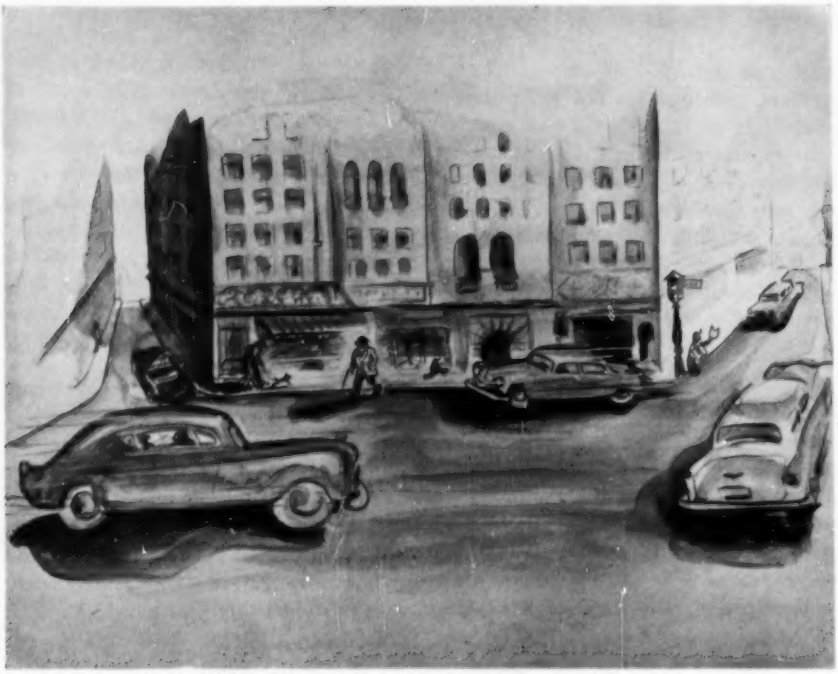


Fig. 1.—Artist's conception of fatal jaywalker accident.

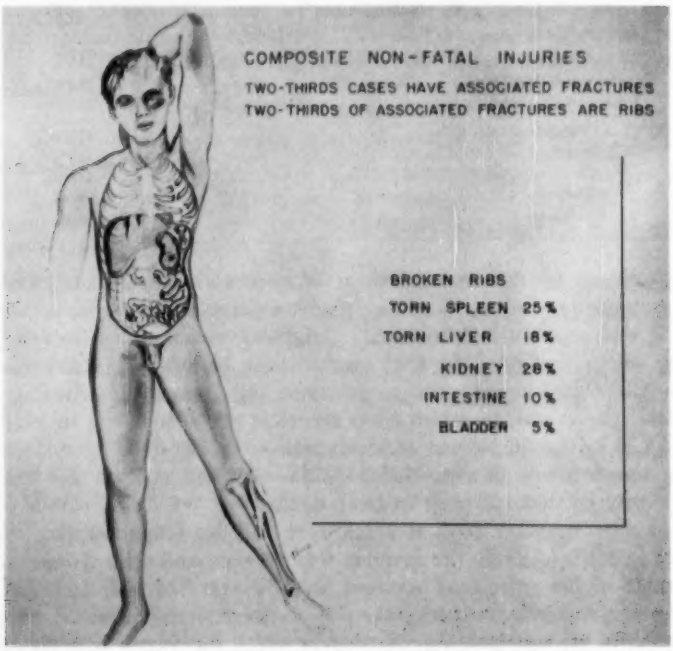


Fig. 2.—Frequency of viscus injuries in nonpenetrating abdominal trauma.

years old, married, a business employee, foreign born, who is killed crossing in a midblock during early evening of a weekend in a little local business district near his home [3] (Fig. 1).

The nonfatal case reaching a hospital presents the composite picture of a male in his middle 40's in shock, exhibiting some degree of head injury, having in two out of three instances a fracture, two-thirds of which will be in the thoracic cage.[1] Intra-abdominal injury will occur 7 out of 10 times in one of the fixed organs, namely, kidney, spleen, liver, or pancreas. In 2 out of 10 instances a hollow viscus, bladder or bowel, will be ruptured. One out of 10 cases will have isolated or severe abdominal wall injury.[4] Many of the severe internal injury cases will show no external wall trauma, a deceptive picture (Fig. 2).

The incidence of viscus injuries as reported from four sources is reviewed. Dissimilarity in incidence between general and private hospitals is understandable. Averages of organ injury from nearly 800 consolidated cases is presented.*

Fixed or Nonfixed Organ

Fixed organs	70%	Kidney	28%
		Spleen	25%
		Liver	18%
Nonfixed	20%	Small bowel	10%
		Bladder	5%
		Misc.	5%
Abdominal wall	10%		

Frequency of Organ Damage

	MGH[6]	Okla[5]	Holly[1]	LAC[1]	Harlem[6]	
No. cases	200	65	163	225	138	791
Kidney	45.5	23	19.0	27	Not. Rep.	28%
Spleen	19.0	9	13.5	45	38.4	25%
Liver	9.5	14	15.0	16.8	36.0	18%
Intestine	9.5	11	22	6.6	19.5	10%

It is noted that the kidney is damaged in 28%, the spleen in 25%, for practical purposes almost equal frequency. The liver is injured in 18%, the gastrointestinal tract in 10%. With these facts in mind a surgeon should be alert to potential lesions in order of likely occurrence and can set up an orderly program of investigation arranged in four components of study for purposes of completeness.

I. CLINICAL STUDIES

Clinical study must be immediate, frequently repeated, although the case may originate and continue at awkward, inconvenient hours. Repetitive examinations of blood pressure, pulse, respirations, and temperature are routine and mandatory, done at hourly intervals. Nothing will supplant careful repetitive clinical study to detect variable significant clinical signs.

II. LABORATORY STUDIES

Laboratory studies must include at the onset routine standard tests, as complete blood count and urinalysis, the urine obtained by catheter at once if required. A hematocrit reading must be done at onset. This is considered the most reliable

* References 1, 4, 5, and 6.

test of the status of the circulating blood, provided adequate hydration is maintained. Blood volume varies greatly in shock, resulting in wide error in evaluation of blood status by routine blood count. This initial blood study should include a blood grouping for purposes of transfusion and a blood amylase determination. The hematocrit determination should be repeated at frequent intervals, the blood amylase at 12 and 24-hour intervals. Blood bilirubin estimations will be useful at a later date in suspected liver injury.

III. X-RAY STUDIES

Minimal x-ray studies must include the following films: (1) upright chest, (2) lateral decubitus of the abdomen, and (3) AP recumbent of the abdomen to demonstrate the pelvis. These films will evaluate the thoracic cage for fractured ribs and the pelvis for fracture and will delineate air as located within the bowel and/or peritoneal cavity or free in the retroperitoneal space. Of great importance is the repeat flat and lateral decubitus films for identification of fixed or shifting air shadows. At this initial x-ray study, should hematuria be present, a cystogram or excretory urogram may be immediately valuable. Shock may necessitate bedside portable films.

IV. SPECIFIC DIAGNOSIS

Specific diagnostic investigation may include abdominal tap by spinal puncture needle with entry in four abdominal quadrants, repeated if required. It is inexcusable to neglect this procedure in circumstances in which associated injuries may mask abdominal complications, as in (1) the unconscious patient, (2) the unrelieved persistent shock case, and (3) in instances in which known concealed hemorrhage in such cavities as the pleura or retroperitoneal space may predominate in significance over concomitant abdominal lesions which coexist.[7]

Comprehensive Investigation

I. Clinical study
   1. Immediate clinical examinations
   2. Repeat clinical examinations to include blood pressure, pulse, temperature, etc.

II. Laboratory
   1. Complete blood count, urinalysis
   2. Immediate hematocrit; repeat hematocrit
   3. Immediate blood grouping
   4. Immediate blood amylase determination—repeated at 6, 12, and 24 hours

III. X-ray (bedside)
   1. Immediate
      Upright chest
      Lateral decubitus
      Flat abdomen
   2. Repeat upright, lateral in 6 and 12 hours if indicated

IV. Special diagnostic study
   1. Abdominal tap
   2. Excretory urogram; gravity cystogram

In each instance before laparotomy is conducted, traumatic peritonitis or peritonism must be excluded. This syndrome, resulting from blunt shock to the celiac plexus, back, or thorax, commonly subsides under customary shock therapy. Laparotomy is indicated in the following instances:

1. Evidence of internal injury with continued and/or recurrent active bleeding
2. Definite evidence of hollow viscus rupture
3. Kidney damage with excessive hemorrhage or with extravasation
4. Unexplained abdominal pain, tenderness, and rigidity
5. Regardless of laboratory data, should the surgeon be unable positively to exclude abdominal trauma

The optimum time for laparotomy is largely determined by the shock status. Treatment of shock includes physical and mental rest, particularly pain relief and replacement into the circulation of whatever fluid has been lost.[8] Pain and mental anxiety may be relieved by morphine effectively given intravenously unless contraindicated by cranial injury, warmth without excess blanketing, and blood volume restoration by blood plasma or a plasma volume expander. Shock from hemorrhage requires whole blood returned into the circulation faster than it is lost, which may require more than one portal of entry. In cases in which blood is lost rapidly it is never possible to know how long or how short a period of improvement may continue during replacement; consequently, it is important to intervene during the upswing of recovery. Oxygen administration, use of vasomotor drugs, and in some instances possibly adrenal cortex agents are valuable. With stability of circulation established, surgery may safely follow. Where response to shock is good but of short duration immediate surgery to control hemorrhage is essential. Where response is poor or nil a desperate situation prevails, testing clinical judgment. In critical instances, supported by massive multiple transfusions, laparotomy may be performed in the presence of unrelenting shock with occasional satisfactory results.

Knowledge of distinguishing diagnostic features of various viscera injured is essential. The spleen, liver, and pancreas are the three fixed organs within the abdomen subject to most frequent injury. The retroperitoneal kidney does not enter into the problem of abdominal laparotomy. Hollow structures subject to injury are the bladder and gastrointestinal tract.

Kidney

The kidney presents the most frequent organ injured (28%) but exhibits the least dramatic and threating emergency. These victims are least able to identify the site of their objective distress. Right flank trauma causes renal injury more often than hepatic damage, whereas left flank trauma causes spleen damage more often than kidney damage. The kidney may sustain parenchymal contusions with microscopic hematuria, cortical fracture with or without disruption into the pelvis or calyx or pulpification. Flank tenderness or a palpable mass with evidence of extending hemorrhage may call for excretory urogram study, which should clarify the status of the contralateral kidney as well as delineate the pathology in the traumatized kidney, all of which may establish indications for retrograde urograms. Surgery may evacuate a perirenal hematoma, repair a laceration with ribbon surgical gut or effect partial or complete nephrectomy.

Spleen

Of the abdominal organs injured, the spleen experiences capsular tears, subcapsular hematomas, which in 2 out of 10 instances may suddenly rupture at later date with profuse hemorrhage, or major frank severe lacerations. The problem is that of concealed hemorrhage. Left upper quadrant pain, tenderness, and rigidity, with elevation of the left diaphragm with increased soft tissue density on x-ray film and possible stomach displacement to the right should aid in diagnosis. One-seventh of all splenic ruptures occur as delayed severe abdominal catastrophies. In this lesion abdominal taps may be of particular value. Immediate splenectomy is ideal treatment.

Liver

The liver, injured almost as frequently as the spleen (18%), suffers tears of the right lobe six times as frequently as of the left, with stellate rupture of the dome in 43% of cases.[7] Laceration may involve only the hepatic capsule, or there may be a subcapsular hematoma, frank laceration, or central rupture with subsequent cystic abscess formation. The presenting problem again is hemorrhage, in which instance a large amount of blood may be found in the abdominal cavity for the reason that hepatic veins are valveless, plus the fact that bile-blood mixtures result in a poor coagulum in this friable viscus. Diaphragmatic movement aggravates hemorrhage, the extent of which determines the clinical course, massive hemorrhage resulting in rapid death. In a group of patients with ruptured liver, one-third died at the site of injury, 38.5% died in six hours, and 48.6% lived sufficiently long for clinical study with gross mortality extending upward to 81%.[7] Patients with fractured livers commonly have sustained severer trauma than those with a torn spleen, 70% having severe associated injuries, whereas 50% of splenic traumas have severe associated injuries. In addition to shock and hemorrhage, diaphragmatic peritoneal irritation may be evidenced by right shoulder pain. An elevated motionless diaphragm is commonly observed. At laparatomy hepatic bleeding, which was partially controlled by contraction of the abdominal muscles, may become torrential as soon as anesthesia releases this splinting. Such bleeding may immediately be controlled by grasping the structures in the free edge of the gastrohepatic omentum. Subsequent bleeding is arrested by coaptation of the lacerated edges with the use of interlocking mattress sutures; in slighter cases by packing with gauze saturated in thrombin solution, absorbable gelatin sponge (Gelfoam), or oxidized gel pack.[9]

Pancreas

The pancreas, the fourth solid organ subject to trauma, is injured commonly concomitantly with the duodenum. Walters[10] recently reported on traumatic pancreatitis at the Los Angeles General Hospital between 1939 and 1951, in which period a total of 1,328 cases of pancreatitis were studied. Of these 42 were traumatic, 18 being of the closed nonpenetrating type. Contusion of the abdomen against the steering wheel was the principal cause of injury. The closed group carried a 27.8% mortality. Damage was thought to originate from direct contusion of the pancreas with rupture of minor or major ductal components and multiple minor acinar ruptures originating from an acute rise in interductal pressure as force is applied diffusely over the extrahepatic biliary tract. Pain of greatest intensity in the epigastrium is associated with abdominal tenderness in a transverse zone. Hyperamylasemia is a finding of greatest significance. This study should

be made routinely, inasmuch as accurate diagnosis of pancreatic injury has medical-legal value. Pseudocysts have followed pancreatic trauma in a recent study, 3 out of 18 such instances being noted. The associated duodenal rupture can best be identified by extravasation of iodized oil (Lipiodol) following a swallow of a small amount of this material, which is considered a safe procedure. Treatment of uncomplicated traumatic pancreatitis is medical, using nasogastric suction with electrolyte replacement, adequate atropinization, administration of methantheline (Banthine) bromide, use of wide-spectrum antibiotics, and sympathetic block from T4 to T9 with β-diethylaminoethyl-p-ethoxy benzoate hydrochloride (Intracaine). Should surgery be inadvertently performed or a concomitant lesion treated, abdominal pancreatic drainage should follow.

Bladder

Bladder rupture occurs in 5 to 10% of cases. In 75% of bladder ruptures at the Los Angeles General Hospital, the condition was associated with fractures of the pelvis. Signs of urinary injury are capricious. Paradoxically, with extensive bladder rupture gross urine may be clear; in 25% of cases of fractured pelvis with blood in the urine no serious bladder tear was found. For diagnosis, catheterization with attempted recovery of a measured amount of instilled fluid is an unreliable criterion of disruption, since intraperitoneal extension of a laceration may allow complete recovery of the fluid inasmuch as a plug of omentum or other viscera may close the bladder rent or the catheter may enter the peritoneal cavity, with subsequent recovery of all fluid from this space. The constant desire to void is perhaps more characteristic than any other sign. Excretory urogram studies may prove deceptive in interpretation of bladder injury, the bladder showing a normal rounded contour frequently although ruptured. Cystogram studies using 5% methiodal (Skiodan) or sodium iodide solution passed through an 18F. catheter connected to a 4 oz. (113 gm.) Asepto syringe introduced by gravity constitutes a safe technique.

Gastrointestinal Tract

The gastrointestinal tract suffers trauma in approximately 20% of instances, with a gross mortality of 25%. Small bowel perforations show a mortality of 15% when detected and repaired within four hours, 44% when repaired between four and eight hours, and 70% when repaired after the 12th hour.[6] The esophagus is subject to trauma at the level of the diaphragmatic hiatus, wherein tears will produce emphysema in the neck with pneumothorax. The stomach rarely suffers rupture; the signs are those of perforated gastric or duodenal ulcer. Small bowel damage occurs with greatest frequency nearest the duodenojejunal flexure, or within its first 3 or 4 ft. At the distal extremity of the small bowel two terminal coils of ileum come in contact with the sacral promontory and are subject to trauma. The mid 12 to 13 ft. descends vertically along the mesial border of the left psoas muscle into the sanctuary of the pelvis and shows less frequent laceration.[10] Multiple lacerations occur in 10%. Free air in the abdominal cavity is seen in less than 50% of cases. Hemorrhage is not an outstanding feature. Contusion of the intestinal wall with secondary perforation or incomplete tear of the mucosa-muscularis with temporary serosal integrity may delay recognition of the severity of the problem. Complete rupture may be single or multiple and may be associated with mesenteric contusions, tears, or detachments in which instances, in addition, there

will also be severe hemorrhage. However, the commonplace features of small bowel rupture are evidences of spreading peritonitis, indicated by pain, tenderness, and rigidity. Localized signs are commonly absent for 3 to 12 hours. Repair of the lacerations needs no detailed description.

Duodenal Rupture

A less common, frequently unrecognized but grave, gastrointestinal rupture is that of the duodenum, which occurs in an average of 10% of all gastrointestinal ruptures.† Of these 25% will be retroperitoneal, with 90% in the second or third portions. The mortality of the lesion has ranged upward to 91%. Better recognition of the condition is shown by a report of 25 cases in 1952 with a mortality reduced to 20%. This rupture occurs when sudden unexpected force from front or rear strikes the relaxed abdomen with the pylorus closed and the duodenojejunal angle acutely flexed, in which instance a duodenal air trap over the spinal column results in vulnerability of the retroperitoneal area. Associated injuries, mainly nonabdominal, such as cranial, spinal, chest, or extremity traumas, frequently leads to delayed recognition. The significant features of the lesion are brief initial shock with a delusive recovery period followed by a quiescent phase in which the patient is relatively uncritical for 24 to 48 hours after which spreading duodenal contaminants result in secondary shock with peritonitis. Of greatest importance is the flat abdominal film.‡ The initial flat film may not be helpful, but repeat films made in prone or supine, the lateral decubitus, and the upright positions will subsequently show retroperitoneal air infiltration, which may outline the kidneys, extend along the vertebral column or the crus of the diaphragm, obliterate the renal or psoas shadows, or extend into the mediastinum. An iodized oil swallow may be helpful in demonstrating extravasation; barium never should be used. At laparotomy any associated lesions must be repaired. Duodenal exposure is readily accomplished by medial rotation of the duodenum or transgastrocolic incision. The laceration is repaired with retroperitoneal drainage. Supportive electrolytes are given. Complications that may ensue are external duodenal fistula; retroperitoneal cellulitis with subphrenic, subhepatic, or pelvic peritoneal abscess; fistula to colon or pancreas, and, finally, stenosis of the duodenum. The following illustrative case is reported.

J. A. S., a 24-year-old oil-field roughneck, injured on Dec. 10, 1952, was admitted to the hospital 45 minutes after being squeezed between a loading platform which he faced and a truck compressing him from the rear. Admission examination showed moderate shock with severe abdominal pain. Fractures of the right second and third lumbar transverse processes were noted. No abnormal air shadows were observed on the preliminary film. During the second hour of observation he vomited; the temperature was 99.4 F., pulse rate 80, and respiration rate 20. Nasogastric suction was introduced. The findings remained relatively unchanged until the 26th hour, at which time blood pressure, which had been stabilized at 130/80, fell and pulse rate suddenly accelerated to 140. A repeat abdominal film made just previous to this development had demonstrated retroperitoneal air. Serum bilirubin and blood amylase studies were initially normal and remained normal on repeat. Abdominal tap had failed to reveal blood or free peritoneal fluid. Results of hematocrit studies had remained stabilized. Abdominal pain and rigidity intensified. Laparotomy was performed on the 30th hour. All fixed organs were examined and found intact. The gastrocolic omentum was discolored and edematous. When this structure was opened a large tear of the retroperitoneal junction of the third and fourth portions of the duodenum was displayed (Fig. 3); this was repaired

† References 12 to 20.

‡ References 21 to 26.

Fig. 3.—Artist's sketch of ruptured duodenum.

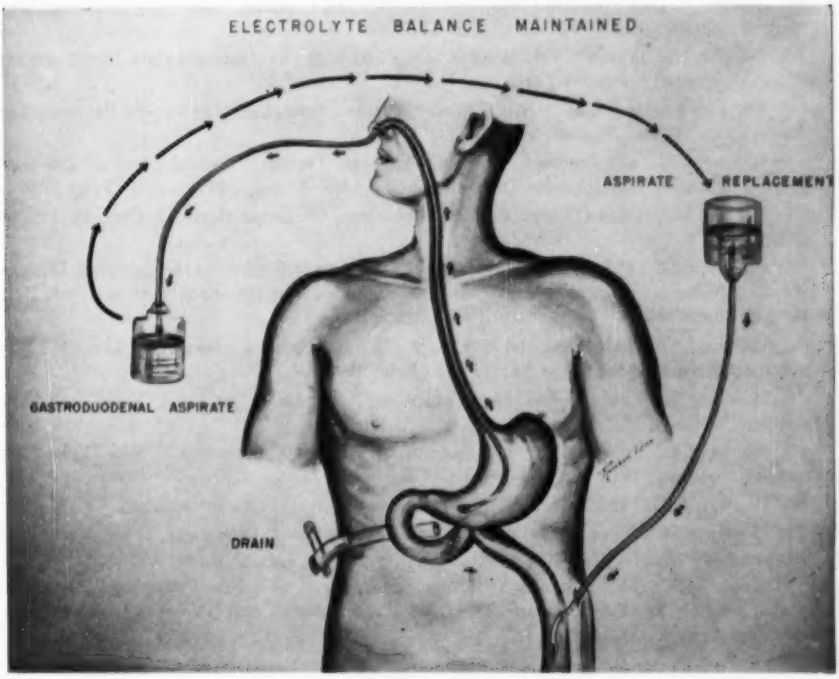


Fig. 4.—Repair of ruptured duodenum and replacement of electrolytes.

and a Chaffin retroperitoneal drain was brought out through the right flank. Complementary jejunostomy was done to permit replacement of aspirated gastric contents in an effort to maintain electrolyte balance (Fig. 4). This was accomplished, permitting removal of the catheter on the 13th postoperative day. The patient was released, apparently recovered, on the 16th postoperative day. However, five days thereafter lower right quadrant pain with pyrexia resulted in an excretory pyleogram being done, which demonstrated displacement of the right lower ureter and superior lateral aspect of the bladder. Obviously an extraperitoneal pelvic abscess was present. This was drained. The patient was released on the 35th day, to be readmitted on the 67th day because of intestinal obstruction. Laparotomy demonstrated this to be the result of an adhesion from the jejunum at the site of jejunostomy reaching to the root of the mesentery, effecting an internal hernial orifice through which small bowel had prolapsed. Release of this adhesion effected complete recovery with discharge on the 81st postoperative day. Subsequent recovery has been complete.

CONCLUSIONS

The automobile leads as a source of civilian trauma, with multiple injuries commonplace. Blunt abdominal viscus ruptures with high mortality must be suspected in all instances. The frequency of incidence of trauma to the various fixed and hollow organs is presented in order to create a composite picture so that the most likely traumas can be preconceived. This should result in a programmed study which will initially include all essential observations, to result thereafter in earlier diagnosis and more prompt treatment. The distinguishing features of rupture of the solid and hollow organs are described, including a detailed account of rupture of the retroperitoneal duodenum, a less common lesion carrying a high mortality.

REFERENCES

1. Collins, D. D.: Traumatic Injuries to the Abdomen and Its Contents, Ann. West. Med. & Surg. **3**:282-286 (Aug.) 1949.

2. Booklet, The Travelers 1953 Book of Street and Highway Accidents Data, The Travelers Insurance Company, Hartford, Conn.

3. The Los Angeles Times, News Release: Careless Jaywalker Hurries His Farewell, Los Angeles Times, March 24, 1948, Pt. 2, p. 1.

4. Welch, C. E., and Giddings, W. P.: Abdominal Trauma: Clinical Study of 200 Consecutive Cases from Massachusetts General Hospital, Am. J. Surg. **79**:252-258 (Feb.) 1950.

5. Burnett, H. A., and O'Leary, C. M.: Peritoneum, Oklahoma Gynec. & Obst. **91**:105-109 (July) 1950.

6. Wright, L. T.; Prigot, A., and Stein, F. E.: Traumatic Rupture of the Intestines Without Penetrating Wounds; Incidence of Subcutaneous Rupture of the Intestines, Harlem Hosp. Bull. **1**:116-139 (Dec.) 1948.

7. Wright, L. T.; Prigot, A., and Hill, L. M., Jr.: Traumatic Rupture of the Liver Without Penetrating Wounds, Arch. Surg. **54**:613-632 (June) 1947.

8. Maingot, R., Editor: The Management of Abdominal Operations, New York, The Macmillan Company, 1953, p. 167.

9. Maingot, R., Editor: The Management of Abdominal Operations, New York, The Macmillan Company, 1953, pp. 1093-1094.

10. Walters, R. L., and Berne, C. J.: Traumatic Pancreatitis, to be published.

11. Maingot, R., Editor: The Management of Abdominal Operations, New York, The Macmillan Company, 1953, pp. 1088-1089.

12. Estes, W. L., Jr.; Bowman, I. L., and Merlecke, F. F.: Non-Penetrating Abdominal Trauma with Special Reference to Lesions of the Duodenum and Pancreas, Am. J. Surg. **37**:434-453 (March) 1952.

13. Counseller, V. S., and McCormack, C. J.: Subcutaneous Perforation of the Jejunum, Ann. Surg. **102**:365-374 (Sept.) 1935.

14. Johnson, M. L.: Traumatic Retroperitoneal Rupture of the Duodenum, Arch. Surg. **48-49**:372-381 (April) 1948.

15. Simpson, J. A.: Traumatic Retroperitoneal Rupture of the Duodenum, Brit. J. Surg. **37**:483-485 (April) 1950.

16. Siler, V. E.: Management of Rupture of the Duodenum Due to Violence, Am. J. Surg. **78**:715-732 (Nov.) 1949.

17. Newell, R. B., Rosenbaum, C. R.: Traumatic Retroperitoneal Rupture of the Duodenum, Ann. Surg. **134**:277-278 (Aug.) 1951.

18. Sarnoff, J., and Oremland, B. H.: Traumatic Rupture of the Duodenum, Surgery **14**:272-277 (Aug.) 1943.

19. Ficona, B. J.: Traumatic Perforations of the Small Intestine Due to Non-Penetrating Abdominal Injuries: A Survey of 18 Cases, Surgery **15**:465-475 (March) 1944.

20. Cohn, T., Sr.; Hawthorne, H. R., and Frobese, A. S.: Retroperitoneal Rupture of the Duodenum in Non-Penetrating Abdominal Trauma, Am. J. Surg. **84**:293-301 (Sept.) 1952.

21. Sperling, L., and Ryler, L. G.: Traumatic Retroperitoneal Rupture of the Duodenum, Radiology **29**:521-524 (Nov.) 1937.

22. Ottenheimer, E. J., and Gilman, R. L.: Rupture of the Retroperitoneal Duodenum: Report of a Case, New England J. Med. **222**:251-253 (Feb. 15) 1940.

23. Vigya, O. S.: Emphysema as a Symptom of Ulcer Perforation, Zentralbl. Chir. **53**:627-632 (June 26) 1920; Abstracted J. A. M. A. **87**:986 (Sept. 18) 1926.

24. Sperling, L., and Ryler, L. G.: Traumatic Retroperitoneal Rupture of the Duodenum, Radiology **29**:521-524 (Nov.) 1937.

25. Jacobs, E. A.; Culver, G. J., and Koenig, E. C.: Roentgenologic Aspects of Retroperitoneal Perforations of the Duodenum, Radiology **43**:563-571 (Dec.) 1944.

26. Koenig, E. C., and Culver, G. J.: Retroperitoneal Perforation of the Duodenum, Radiology **48**:164-167 (Feb.) 1927.

CYLINDROMATA OF MAJOR AND MINOR SALIVARY GLAND ORIGIN

N. W. WAWRO, M.D.
AND
GEORGE McADAMS, M.D.
HARTFORD, CONN.

ACCURATE diagnosis and adequate treatment of neoplastic disease requires knowledge of its natural life history. While this information is currently available for carcinoma of the breast, uterus, colon, and stomach, some neoplasms of salivary gland origin are not properly identified as malignant tumors. Management of this latter group often leads to a sequence of events where initial optimism soon gives way to doubt and, eventually, pessimism colors the treatment and prognosis.

Arising from major and minor salivary gland tissue of the head and neck region is a tumor described variously as "cylindroma," "adenoid cystic carcinoma," "myoepithelioma," "cellular mixed tumor," "adenocarcinoma Grade I," and even "basal cell carcinoma with hyaline stroma." That the clinical and morphological features of this entity are poorly understood is evidenced by the fact that occasionally this lesion has been classified [1] and treated [2] as a benign tumor.

Our experience with 18 cases, and that of others,* indicates that this is a malignant tumor characterized by slow growth, aggressive and multiple recurrence, delayed metastases to regional nodes and distant viscera, and resistance to radiation therapy. It is hoped that review of our material, added to the experience of others, will contribute to a better appreciation of the life history of this entity and encourage more adequate treatment.

MATERIAL AND PATHOLOGICAL DATA

Eighteen cylindromata were obtained from the material in the pathological department of the Hartford Hospital from 1932 to 1951. Twelve arose in the parotid gland, two in the submaxillary gland, three in the palate, and one at the base of the tongue.

CYLINDROMA

Gross.—There is nothing distinctive about the macroscopic appearance of a cylindroma, and it is dangerous to attempt to differentiate it from an ordinary mixed tumor or from an adenocarcinoma on the basis of its gross pathology. It may or may not have an apparent capsule. The lesion usually presents itself as a firm nodule embedded in the salivary tissue concerned and has a grayish color as opposed to the light-tan hue of the surrounding glandular tissue.

Microscopic.—In contrast with the clinical appearance, the microscopic examination of a cylindroma can be most characteristic. The classic cylindroma consists

From the Departments of Surgery and Pathology, Hartford Hospital.

* References 3 to 7.

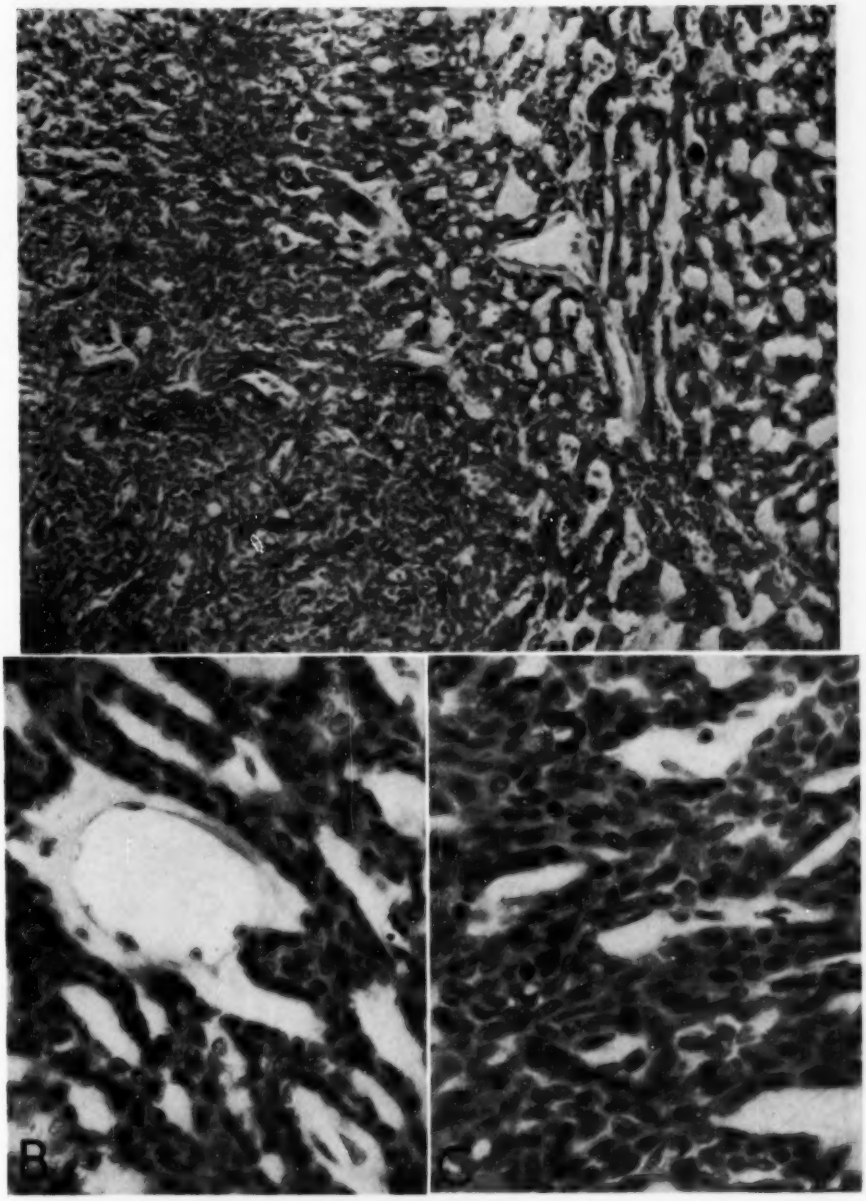


Fig. 1.—*A*, microscopic field demonstrates histologic cytology and arrangement characteristic of "classic" cylindroma. Note cellularity, adenocystic pattern, and lack of myxomatous elements; × 220. *B* and *C*, high-power fields of specimen (*A*), showing small empty "cylinders" lined by uniform cuboidal cells continous with and of same histology as stromal cells. Lack of anaplasia and mitotic activity belies infiltrative and potentially malignant character of tumor; × 450.

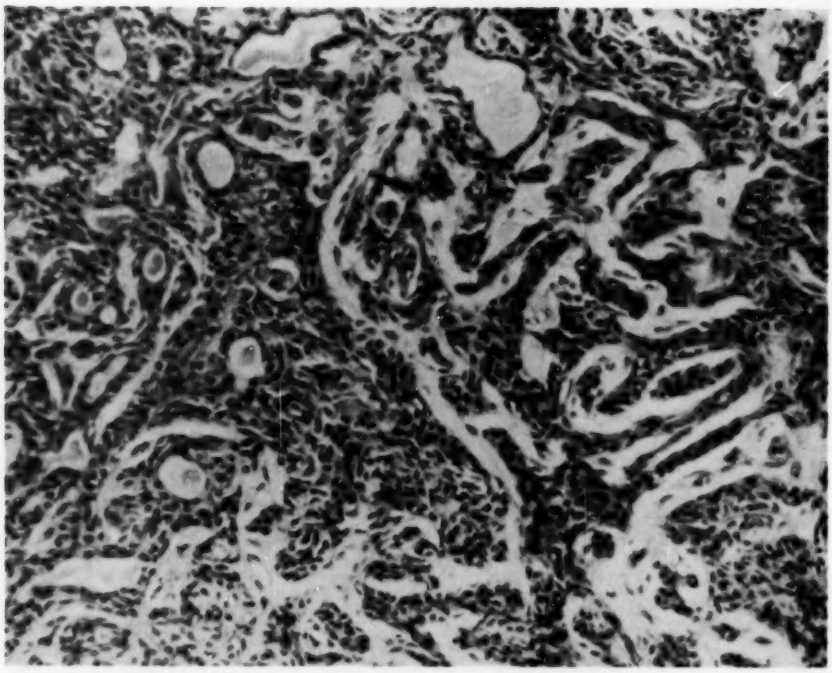


Fig. 2.—Another type of cylindroma. Irregular wavy groups of cells rather than cylinders dominate the arrangement, although cylinders are seen to some extent; × 220.

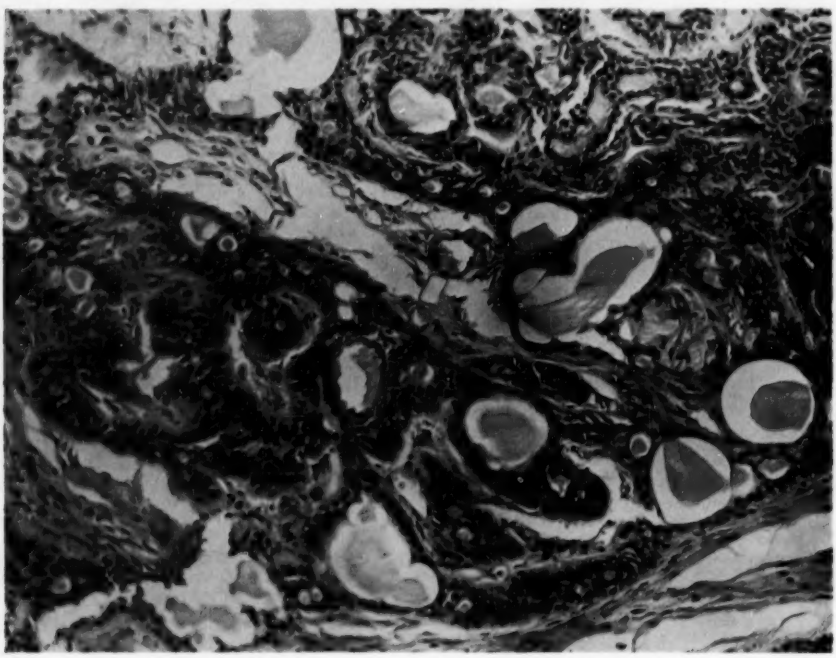


Fig. 3.—Area adjacent to that shown in Figure 2. Relatively large cystic spaces filled with hyalin material overshadow to some extent the dense cylindromatous stroma; × 200.

of fields of dense sheets of tumor cells arranged about small empty spaces or "cylinders." A true glandular pattern is not, however, discernible. The lining cells of these spaces are small and cuboidal with moderate amounts of pink-staining cytoplasm and small, regular, oval, or round nuclei. The uniformity of the cells can be quite striking, and mitoses are often difficult to find (Fig.1).

These lining cells differ in no way from the appearance of the surrounding stromal cells. Not all cylindromata contain this above arrangement exclusively. Often one sees these same cells arranged in wavy tortuous strands (Fig. 2), perhaps interspersed with comparatively large cystic spaces (Fig. 3). Moderate

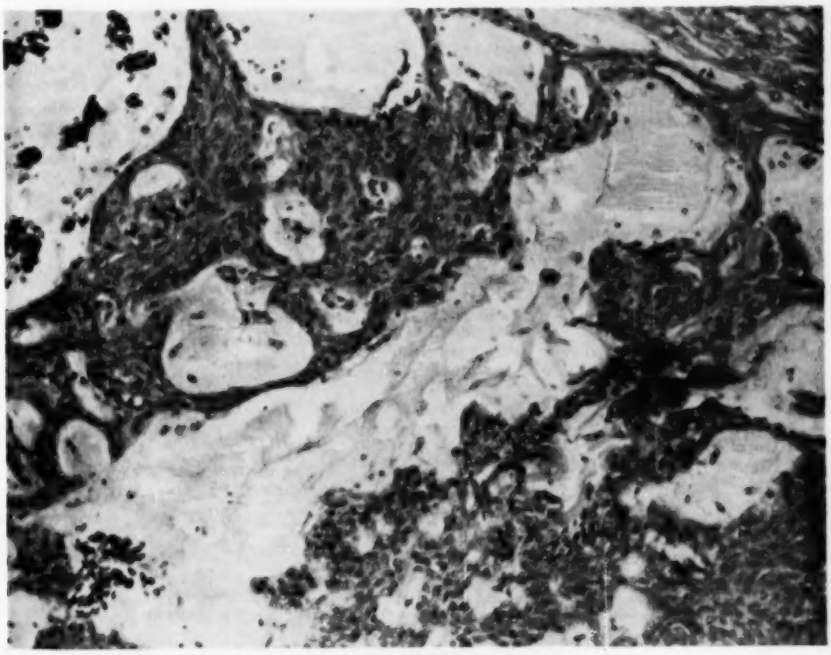


Fig. 4.—Variation of cylindroma. Cellular component surrounded by myxomatous areas as seen in benign mixed tumors; × 220.

amounts of loose myxomatous tissue may be present (Fig. 4); indeed, herein can lie the difficulty of diagnosis. In some cases it is practically impossible to state whether the tumor concerned is a somewhat dense cellular mixed tumor or a true cylindroma with unusually large myxomatous content.

It is interesting to speculate upon the origin of these tumors. The striking histologic similarity among cylindromata, adenocystic basal cell epitheliomata of the skin and breast, and adamantinoma of the jaw is obvious. It must be concluded that cells of the basal portion of the epithelium and/or epithelial derivatives are in the background of the development of each of these tumors and that essentially the same fundamental tumor may be represented in different locations in different sets of circumstances.

TABLE 1.—*Cylindroma*

Patient	Sex	Age, Yr.	Location	Duration, Yr.	Size, Cm.
B. G.	M	56	Parotid	2	2 × 3
A. K.	F	42	Parotid	2	3 × 4
M. K.	M	59	Parotid	18	3 × 4
M. E.	F	62	Parotid	7	12 × 8
A. G.	F	56	Parotid	5	3 × 3
M. S.	F	69	Parotid	8	?
J. L.	M	83	Parotid	20	?
E. H.	F	72	Parotid	14	?
A. J.	F	50	Parotid	10	3
D. H.	F	39	Parotid	5	2 × 3
N. C.	F	79	Parotid	4	3 × 3
A. H.	F	65	Parotid	1	4 × 4
S. B. E.	M	58	Submax.	2	3
M. S.	F	54	Submax.	1	2.5
W. S.	M	16	Palate	?	3
F. H.	F	76	Palate	3	5
R. M.	F	49	Palate	13	3.5
H. R.	F	63	Tongue	2	3 × 5

TABLE 2.—*Results of Treatment*

Patient	Treatment	Results
	Parotid	
B. G.	Parotidectomy and neck dissection	Living 2 yr.; 1 recurrence
A. K.	Parotidectomy	Living 1 yr.; no recurrence
M. K.	Local excision and radium	Dead with one recurrence after 18 yr.
M. E.	Subtotal parotidectomy	No follow-up
A. G.	Subtotal parotidectomy and radium	Dead in 4 yr. with ca. of ovary
M. S.	Local excision and radium	Lost to follow-up after 3d recurrence
J. L.	Local excision	Living 15 yr.; 3 recurrences
E. H.	Local excision	Living 14 yr.; 4 recurrences
A. J.	Local excision	No follow-up
D. H.	Parotidectomy	Living 6 yr.; 3 recurrences
N. C.	Parotidectomy	Living 3 yr. without recurrence
A. H.	Local excision	No follow-up
	Submaxillary	
S. B. E.	Local excision and x-ray therapy	Dead in 4 yr. with disease
M. S.	Local excision	Living 2 yr.; no recurrence
	Palate	
W. S.	Local excision	Living 16 yr. with recurrence
F. H.	Radical excision	Dead in 4 yr. with recurrence
R. M.	Radical resection and x-ray therapy	Dead in 14 yr. with recurrence
	Tongue	
H. R.	Radical resection and x-ray therapy	Living 3 yr.; no recurrence

CLINICAL DATA

Table 1 indicates that in this series cylindromata occurred predominantly in women in the ratio of 13 to 5. The average age of these patients was 57 years, with extremes of 16 to 83 years. The slow growth of this lesion is best demonstrated by

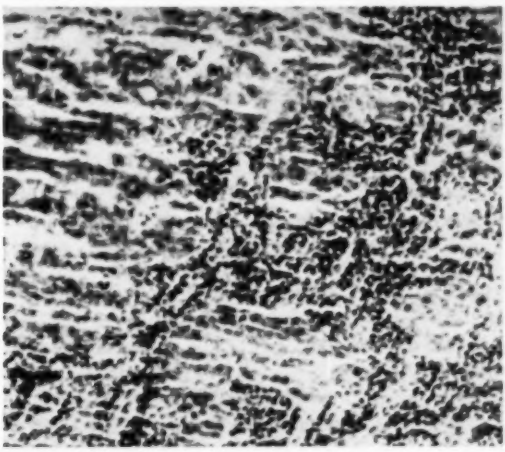


Fig. 5 (Case 7).—Cylindroma, metastatic in lymph node; × 220.

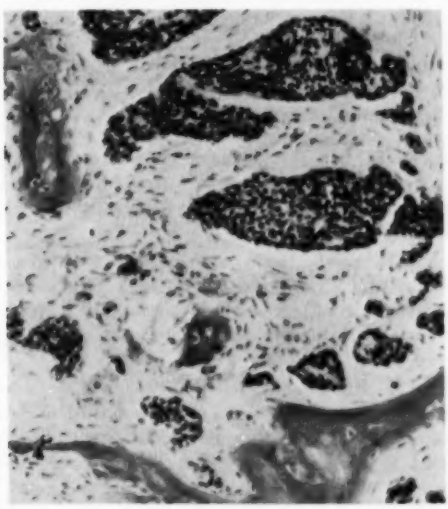


Fig. 6 (Case 7).—Cylindroma, metastatic in bone. Fibrous tissue proliferation is abundant; × 100.

duration of tumor presence measured in years from onset through treatment, resulting in either control of the disease or death of the patient. A few lesions were present for 1 year, but two were present for 20 years, with an average of 8 years. It is significant that three patients had intervals of 10 to 15 years between recurrence.

Tumor size varied from 1 by 1 cm. to 8 by 12 cm., with an average of 3 to 4 cm. Encapsulation was generally poor on both gross and microscopic examination. The commonest symptom was the presence of a mass which presented no features differing from the average benign mixed tumor. Facial-nerve weakness was not apparent in the parotid gland series, and only one patient appeared initially with metastatic disease in cervical nodes. Of 18 patients, 10 demonstrated one to three local recurrences after surgical treatment. Two died of disease, with metastatic regional node involvement in one (Fig. 5) and lymph node and visceral spread (Fig. 6) in the other. Since postmortem studies were not obtained in several patients who died at home, it is impossible to determine incidence of metastases in this group. Table 2 emphasizes the poor results obtained with limited surgery. Seven patients had radical surgery, in four cases as the initial treatment, and in three instances limited surgery after recurrence.

REPORT OF CASES

We believe the following representative cases will best illustrate the behavior pattern of the cylindroma to support our impression that this is a malignant tumor.

CASE 1.—J. L., male, 83. Left parotid lesion of five years' duration removed 15 years ago; recurred five years later and was locally removed. Ten years later (August, 1951) 1 cm. nodule beneath incision noted and removed by limited excision.

CASE 2.—K. M., male, 59. Left parotid tumor removed 18 years ago. Course satisfactory until recurrence 14 years later for walnut-sized lesion of left parotid. Limited enucleation done and patient well for another four years, when death followed due to hypertensive CV renal disease. Patient died at home and postmortem examination was not done.

Comment.—Cases 1 and 2 illustrate the slow growth, with long intervals between recurrence, and the absence of apparent regional or distant metastatic disease. The arbitrary five-year "cure" rate could not be used to evaluate any form of therapy for this neoplasm.

CASE 3.—M. S., female, 75. Left parotid tumor of two years' duration removed six years previously, followed by first recurrence three years later. After removal, patient well for two years, when second recurrence noted and resected, sacrificing the facial nerve. Postoperative radium therapy administered.

CASE 4.—F. H., female, 76. Palatal lesion of three years' duration widely resected in October, 1948. Eighteen months later 2 cm. right alveolar ridge recurrence was widely excised by cautery. One year later, another recurrence, with involvement of the right soft palate noted but not treated at patient's request. No neck nodes or pulmonary metastases noted at any time up through second recurrence.

CASE 5.—D. H., female, 39. Right parotid lesion of two years' duration removed in 1947, followed by recurrence 18 months later. Both procedures consisted of simple enucleation. One year later, January, 1950, four separate nodules were found distributed within the parotid gland. Subtotal parotid resection combined with biopsy of upper neck nodes done at this time, sparing facial nerve and small portion of the deep retromandibular parotid gland. Each separate nodule reported as cylindroma. The cervical nodes were free of metastatic disease. Despite postoperative x-ray therapy to this parotid (at patient's request), two and one-half years later a solitary 0.5 cm. lesion arising from deep retromandibular gland was found over cervicofacial trunk of right facial nerve and resected. Serial chest films have failed to demonstrate metastatic disease.

Comment.—Cases 3, 4, and 5 illustrate a more aggressive and rapid recurrence rate, though still without local or distant metastases. Postoperative irradiation failed to prevent recurrence in Case 6.

CASE 6.—R. M., female, 49. Hard palate nodule first noted in 1936. At biopsy six years later, 1942, specimen reported as cylindroma. Local resection was followed by a course of deep x-ray therapy. Recurrence noted two years later, and second course of deep x-ray therapy administered in 1945, without significant regression. In 1946 radical resection of right hard palate and antrum and exenteration of right orbit carried out. Seven months later a small recurrence within the operative defect was removed by cautery. A third course of deep x-ray therapy was administered in 1948 for fourth recurrence, but, despite this, disease progressed, and patient died at home in 1949, 13 years after onset of lesion. Permission for postmortem examination not obtained, but enlarged hard right cervical nodes were noted in 1947.

CASE 7.—S. B. E., male, 58. Small right submaxillary gland cylindroma enucleated in 1947. Within the next year progressive right cervical pain associated with dysarthria, dysphagia, and dysphonia was noted. Exploration of right upper neck in 1949 demonstrated extensive neoplastic disease infiltrating right carotid sheath up to jugular foramen encasing 9th, 10th, 11th, and 12th cranial nerves. Course of deep x-ray therapy resulted in modest palliation for several months, after which disease process was unchecked. Patient died in 1951. At post mortem, in addition to persistent local disease in right neck, direct invasion of base of skull and metastases to regional lymph nodes and lung were noted.

CASE 8.—B. G., male, 56. Two nodules in right neck unassociated with palpable parotid mass were removed and reported as metastatic cylindroma in cervical lymph nodes. After this, a total right parotid resection with right radical neck dissection was done. Primary cylindroma of deep retromandibular parotid was noted. Ten months later, nodule recurred in right submaxillary triangle, with associated involvement of right mandible. Resection of recurrent mass and adjacent involved mandible was carried out. Pathologic examination confirmed presence of recurrent cylindroma with extension into bone.

Comment.—These three cases demonstrate the rapid and aggressive local recurrence of the lesion, invasion of the surrounding vital structures, and metastases to the regional nodes and viscera. The failure of adequate deep x-ray therapy to prevent recurrence or to achieve cure is again demonstrated.

CASE 9.—H. R., female, 63. A 3 by 5 cm. ulcerating mass at base of tongue symptomatic for two years, and recently condition was associated with hemorrhage, dysarthria, and dysphagia. On review of submitted slide of tongue biopsy specimen, lesion was reported as cylindroma. No evidence of pulmonary or cervical node metastases was noted. Radical resection of base of tongue, including central segment of hyoid bone, was carried out and followed by deep x-ray therapy. No recurrence after two years.

Comment.—The base of the tongue is an unusual location for a cylindroma, although this neoplasm may arise wherever major or minor salivary gland tissue is present. Irrespective of site of origin, i. e., whether major salivary gland or minor salivary gland in oral mucosa, one should expect the same clinical course, and therapy should not differ.

COMMENT

The foregoing case reports demonstrate the natural history of this neoplasm, which we believe is characterized by slow growth, frequent recurrence, delayed metastases, and resistance to irradiation.

We believe that these characteristics make the cylindroma an ideal lesion for radical surgery. Nothing short of a total parotid removal, sparing facial nerve if uninvolved, combined with homolateral radical neck dissection in the presence of enlarged cervical nodes or limited to upper neck dissection in the absence of palpable cervical adenopathy, would satisfy requisites of adequate surgery. A similar

plan for submaxillary gland cylindromas is recommended. When one is faced with a cylindroma arising in minor salivary gland within the palate, cheek, or base of the tongue, a less aggressive attack must be offered, since the anatomical limits and planes are not as apparent, and disability and morbidity from anatomical defects will be greater. Eventually, when the growth is uncontrolled, death from local extension and/or distant metastases will result. Failure to recognize this fact in the past may have been due to lack of long-term follow-up, since it is demonstrated that intervals of from 5 to 15 years may elapse between recurrence.

The experience of other observers, both abroad and in this country, confirms our experience. A 20-year follow-up of cylindromata at the Curie Institute in Paris impressed Baclesse † with the ultimate frequency of visceral and skeletal metastases when the primary lesion was not controlled. In 7 of 11 patients skeletal and pulmonary metastases developed 5 to 22 years after onset of lesion and initial therapy. Furthermore, he proposes intensive deep x-ray therapy for those lesions not amenable to radical surgery, and as a preoperative and postoperative adjunct to surgery. Le Maître [6] concurs with these observations. The Mayo Clinic [3] demonstrates a recurrence rate of 75% with survival 7 to 15 years after 2 to 10 recurrences. Eight deaths in 21 cases were noted within five years; five were due to pulmonary metastases and two cervical node metastases. Postoperative irradiation did not consistently prevent or control recurrence, in their hands. Hager [2] limits his discussion to the palatal cylindromata, emphasizing the high recurrence rate, and recommends a combination of surgery and deep x-ray therapy. Bauer and Fox [1] conclude that this entity is capable of "cancerous alteration."

A strikingly parallel clinical behavior of cylindromata of bronchial tree is demonstrated by Reid.[8] He records the slow growth over an average period of 9 years from onset of symptoms in his first uncured cases, and delayed appearance of metastases 5 to 10 years after detection of tumor. In 14 of 50 cases, which he reviewed, there were proved metastases to lymph nodes and viscera. Although Billroth [9] is credited with the first description of this neoplasm, in 1856, at present, the term cylindroma is not believed to be sufficiently descriptive either of the morphological or of the clinical pattern inherent in this tumor. Several observers‡ have proposed that "adenoid cystic carcinoma" would more accurately represent true character of this lesion.

SUMMARY AND CONCLUSIONS

A group of 18 cylindromata of major and minor salivary gland origin is presented.

The slow growth, high recurrence rate, delayed distant metastases, and resistance to radiation therapy is noted as a characteristic pattern of behavior in some lesions.

Radical surgical removal is suggested as the primary procedure of choice.

Radiation therapy has not significantly controlled growth of cylindromata in this series.

The surgical staff of the Hartford Hospital cooperated by permitting the inclusion of their cases in this survey.

Dr. Robert Tennant, Department of Pathology, gave guidance and aid in this study.

† References 4 and 5.

‡ References 8, 10, and 11.

REFERENCES

1. Bauer, W. H., and Fox, R. A.: Adenomyoepithelioma (Cylindroma) of Palatal Mucous Glands, Arch. Path. **39**:99-102, 1945.

2. Hager, A.: Das Cylindrom des Gaumens, Monatsschr. Ohrenh. **84**:37-40, 1950.

3. Quattlebaum, W.; Dockerty, M. B., and Mayo, C. W.: Adenocarcinoma, Cylindroma Type of Parotid Gland: Clinical and Pathological Study of 21 Cases, Surg., Gynec. & Obst. **82**:342-347, 1946.

4. Baclesse, F.: Radiosensitivity and Metastases Observed in the Course of Cylindromas of the Salivary Glands, Bull. Assoc. franç. étude cancer **29**:260-274, 1940-1941.

5. Baclesse, F.: Les metastases et la Radio-sensibilité des Cylindromes et des tumeurs mixtes des glands salivaires, Rev. Stomatol. **47**:469-474, 1946.

6. Le Maitre, Y.: Etude anatomo-clinique des tumeurs dites cylindromas, Paris, edit Vigot, page 190, 1947.

7. Dockerty, M. B., and Mayo, C. W.: Cylindroma (Adenocarcinoma, Cylindroma Type), Surgery **13**:416-422, 1943.

8. Reid, J. D.: Adenoid Cystic Carcinoma (Cylindroma) of the Bronchial Tree, Cancer **5**:685-694, 1952.

9. Billroth, T.: Untersuchungen über die Entwicklung der Blutgefässe, nebst Beobachtungen aus der königlichen chirurgischen Universitäts-Klinik zu Berlin, Berlin, G. Reimer, 1856.

10. Kramer, R., and Som, M. L.: Cylindroma of the Upper Air Passages: A Cylindromatous Type of Mixed Tumor, Arch. Otolaryng. **29**:356-370, 1939.

11. Guttman, M. R.: Primary Adenocystic Carcinoma or Cylindroma of the Trachea, Ann. Otol. Rhin. & Laryng. **45**:894-901, 1936.

Case Reports

CARDIAC ARREST OCCURRING UNDER TRICHLOROETHYLENE ANALGESIA

Report of a Case with Recovery

LIEUTENANT MELVIN L. BERNSTINE (MC), U.S.N.R.

FOLLOWING its introduction in Great Britain, the use of trichloroethylene as an analgesic agent is being widely accepted in the United States. Because of this increased interest it was felt that a case presentation of a complication with this drug would be of interest. This report is concerned with a cardiac arrest that occurred during analgesia, not anesthesia, with recovery following cardiac massage.

This drug is administered as an analgesic agent by means of special inhalers which draw atmospheric air over the drug with the patient's breaths. A unidirectional valve shunts the exhalations back into the surrounding air. The two most commonly used inhalers in this country are the "Cyprane" and the "Duke" inhalers. The drug is available under the names of "Trilene" and "Trimar."

The subject of trichloroethylene anesthesia is covered excellently in a recent monograph by Ostlere.[1] He reviews all the reported cases of deaths under this agent due to sudden cardiac failure, of which there are 20. Closer examination reveals that in many cases death could be attributed to other causes. Analgesia was a factor in only three of these cases, all of which were maternal. None of the cases were reported in sufficient detail to allow a final judgment.

REPORT OF A CASE

A 19-year-old Marine was admitted to the hospital with missile wounds of both legs and feet. The wounds were rather severe, and he was under surgical treatment, which consisted of repeated débridements and redressings in preparation for skin grafting.

This treatment was quite painful and necessitated some sort of anesthesia. On some previous occasions the patient received thiopental (Pentothal) sodium and nitrous oxide without event. Because it was necessary that this man have many more treatments it was felt that if analgesia could be administered in the dressing room then the trip to the operating room and the need for general anesthesia could be averted.

On April 27, 1953, at 2 p. m. the patient received trichloroethylene analgesia by means of the Cyprane inhaler. The dial on the inhaler was set at "five." The patient was told to breathe deeply, and after approximately two minutes the surgeon started to remove the dressings. The patient complained through the mask that he still felt pain. The setting was changed to "seven," and the patient was told to breathe faster and deeper. He did his but still made complaining signs by waving his hand in the air during the removal of the dressings. Suddenly, about four or five minutes from the start of inhalation, the patient's hand stopped waving and fell to his side. He showed gasping respiratory movements occurring infrequently with pallor and absence of a palpable pulse. Mouth-to-mouth artificial respiration was instituted until oxygen was procured, which took about three minutes. In another two minutes, or a total of five minutes after the onset of the clinical cardiac arrest, the chest was opened in the fourth left interspace. Simultaneously an endotracheal tube was passed and the patient given oxygen through this tube. A dilated heart in asystole was seen. There was no fibrillation. Massage was instituted immediately and 10 cc. of 1% procaine hydrochloride was injected into the pericardial sac. An intravenous injection was started with saline, and blood was ordered. For 25 minutes massage was continued and then 2 cc. of a mixture of 1% procaine and 0.1% epinephrine was injected, 1 cc. into the right ventricle and 1 cc. into the myocardium. There was no improvement seen from

this injection or from the massage. Peripheral pulses were felt only during massage, and upon cessation of massage the pulses disappeared and the heart beats became weaker and weaker. The massage was continued, and when the blood arrived 200 cc. was given intravenously and 300 cc. into the femoral artery. Five hundred milligrams of procaine amide (Pronestyl) hydrochloride and 10 cc. of 1% procaine were given intravenously. At this time an electrocardiograph was set up, and the tracing was interpreted as showing ventricular fibrillation. This was approximately 30 minutes after the opening of the chest. Massage was stopped, and this fibrillation then turned into ventricular tachycardia. Massage was then again instituted, and after a

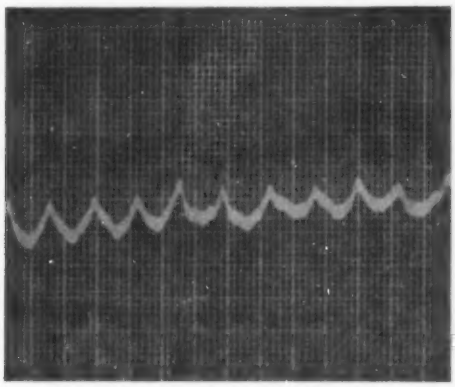


Chart 1.—Electrocardiogram, 30 minutes after start of massage.

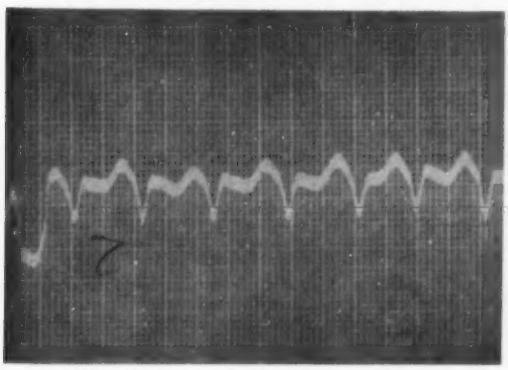


Chart 2.—Electrocardiogram, at closure of chest.

total of 45 minutes of massage the heart showed a fairly forceful but quite rapid rate of contraction. There were good peripheral pulses present. Prior to this, upon cessation of massage, the heart beat became weaker and weaker, threatening to stop. However, now the blood pressure was 110/80, and the electrocardiogram was normal. Again the above mixture of procaine and epinephrine was injected into the right ventricle and myocardium, and the chest was closed in layers.

Five hours later the patient showed normal pupillary reflexes bilaterally and a regular pulse with a rate of 140. He was not conscious and thrashed about. His temperature was 102 F. Phenobarbital sodium was used for sedation.

Seven hours later the patient did not show much change except for a spastic left arm and some clonic convulsions. For the next two days his condition remained about the same. He

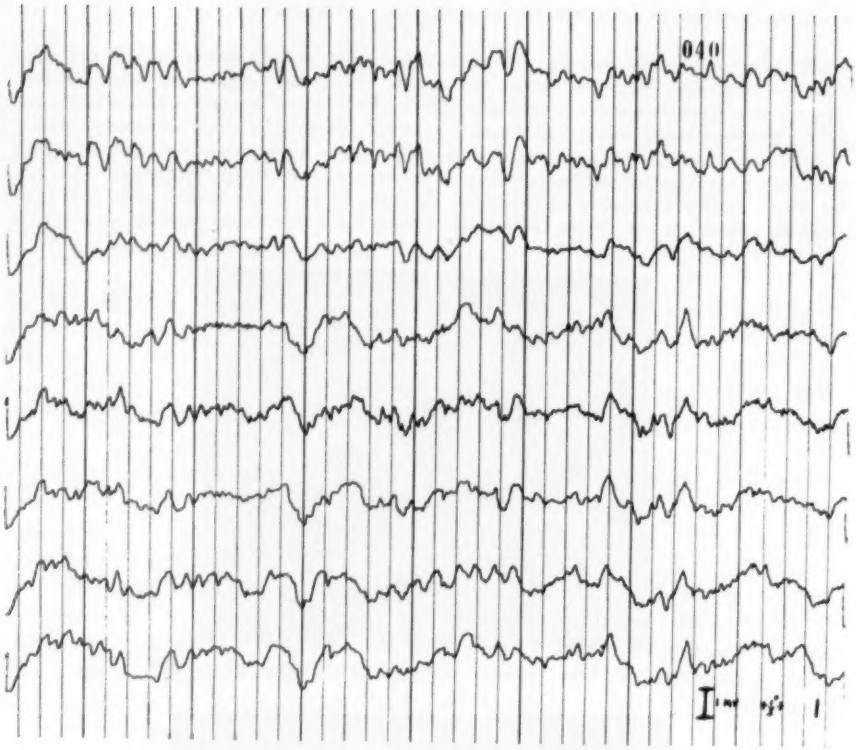


Chart 3.—Electroencephalogram.

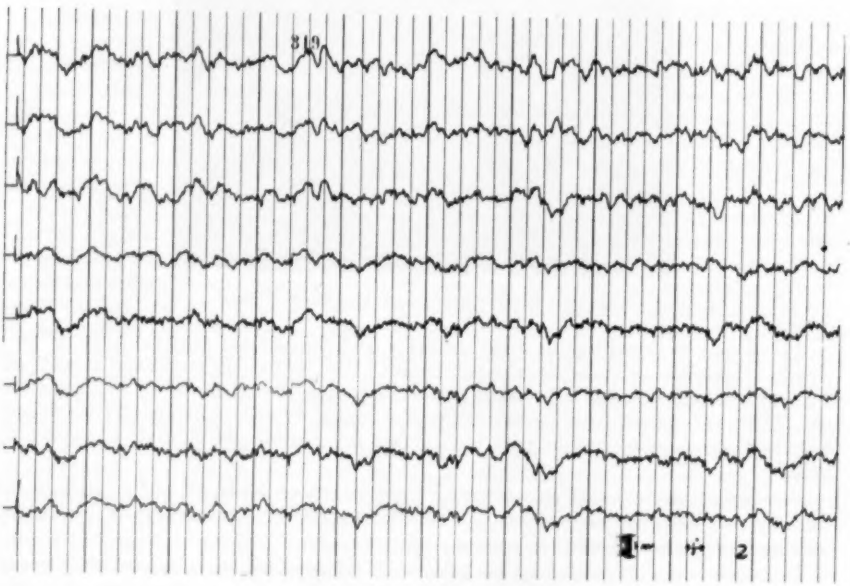


Chart 4.—Electroencephalogram.

seemed cooperative and attempted to answer questions. He knew his last name and recognized the nurse as such. His speech was markedly slurred. The thoracotomy tube was removed at this time. The third day there was no change. On the fourth day the patient seemed to take a turn for the worse. He became quite drowsy and restless. He seemed to lose what little contact he had with his environment. It was thought that this perhaps was due to cerebral edema and he was given a unit of serum albumin intravenously. On the fifth day he was still drowsy and restless and less clear than previously. On the sixth day he had a neurologic examination and was found to be disoriented as to time, place, and person. He showed visual agnosia with a dysarthritic and nasal voice. The fundi were normal and the cranial nerves intact. The pupils were normal. There was no rigidity or spasticity. He had an action tremor.

The patient had electroencephalograms taken on four occasions after his cardiac arrest. These will be discussed below.

One month after the cardiac arrest the patient was evacuated by ship to the United States. He showed marvelous improvement at this time and had very few neurologic sequelae. His

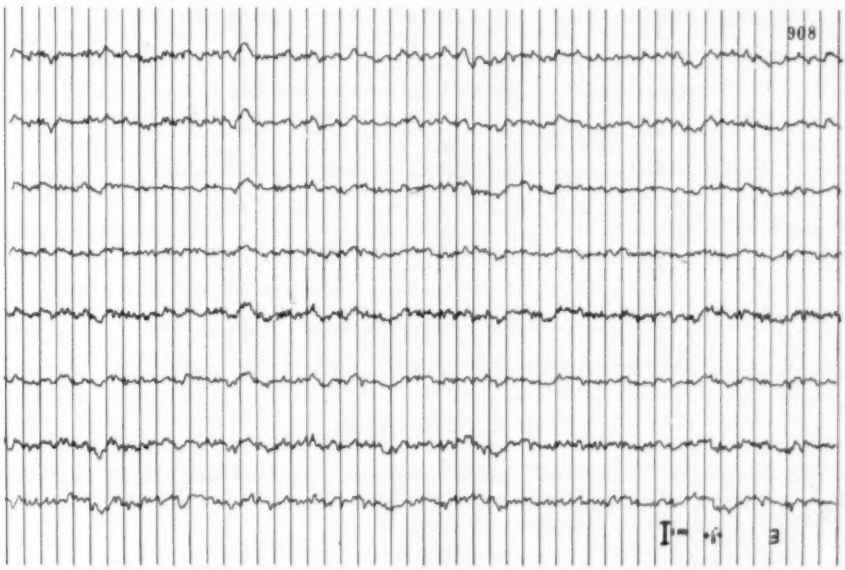


Chart 5.—Electroencephalogram.

mental ability still required study and evaluation, as there was some deterioration. Whether or not this will improve will take watching over a period of a year or so. It is felt that he will eventually make an almost complete recovery.

ENCEPHALOGRAMS

Technique (Seven Days).—Sixteen-lead monopolar and bipolar recording from frontal, temporal, parietal, and occipital areas, bilaterally (Chart 3).

Results: Basic rhythm is poorly modulated 2 to 5 cycles per second (cps) slow activity of moderate to high amplitude which is diffuse, without focal abnormality or paroxysmal dysrhythmia. The patient's continued movement caused considerable artifact throughout the record.

Impression: Abnormal EEG.

Clinical Implication: Indicative of diffuse brain damage due to cerebral anoxia.

Technique (17 Days).—Sixteen-lead monopolar and bipolar recording from frontal, temporal, parietal, and occipital areas, bilaterally (Chart 4).

Results: Basic rhythm is 5 to 8 cps activity in those runs that are free of artifact in this confused and disoriented patient.

Impression: Abnormal EEG.

Technique (24 Days).—Sixteen-lead monopolar and bipolar recording from frontal, parietal, temporal, and occipital areas, bilaterally (Chart 5).

Results: Basic rhythm consists of circa 10 cps poorly modulated alpha activity of moderate to low amplitude. There is superimposed 3 to 6 cps slow activity in all leads of relative higher amplitude.

There is no lateralized abnormality. There is no focal abnormality in the bipolar runs.

Impression: EEG abnormal because of generalized slow activity in the 3 to 6 cps range.

Clinical Implication: EEG shows less slow activity than in the initial record of this series.

Technique (30 Days).—Sixteen-lead monopolar and bipolar recording from frontal, parietal, temporal, and occipital areas, bilaterally (Chart 6).

Results: Dominant rhythm consists of alpha activity of moderate amplitude. There is some superimposed theta activity, which is not so marked as in the recording made May 21, 1953.

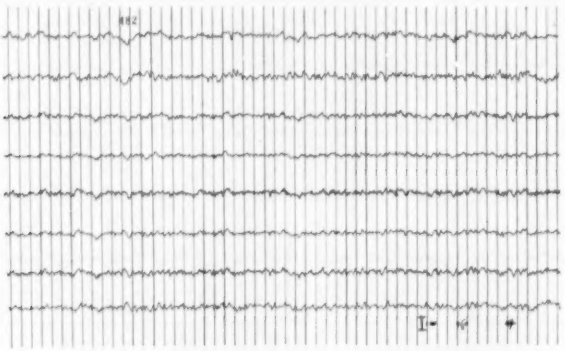


Chart 6.—Electroencephalogram.

Bipolar recording revealed no localized abnormality. Hyperventilation caused moderate slowing. Solving problems which patient could not solve (e. g., 5 times 15), hand clap, and shouting at patient did not change the spontaneous activity.

Impression: Borderline abnormal record because of generalized theta activity.

Clinical Implication: This record shows significant improvement, as compared with previous records.

SUMMARY

This is the report of a case of cardiac arrest occurring under trichloroethylene analgesia in which the patient was treated with cardiac massage and recovered. The massage was started rather late as far as cases of cardiac arrest are concerned, the time being approximately five minutes.

Apparently the arrest was due to an excessively high concentration of the drug in the body, which exerted a direct myocardial toxic effect. It should be remembered that this complication can occur even under analgesia and that all equipment necessary for its treatment should be immediately available. This is especially important as this method of analgesia is commonly used in the physician's office.

REFERENCE

1. Ostlere, G.: Trichlorethylene Anæsthesia, Edinburgh, E. & S. Livingstone, 1953.

SPONTANEOUS PERFORATION OF COMMON BILE DUCT

RICHARD J. CHODOFF, M.D.
AND
ROBERT W. LEVIN, M.D.
PHILADELPHIA

SPONTANEOUS rupture of the common bile duct is an extremely rare condition, as evidenced by the paucity of reported cases. In 1912 McWilliams [1] reviewed 90 cases of spontaneous rupture of the biliary tree, of which 4 were in the common duct. These were cases in which calculi were present in the common duct and in which there was no previous history of operative procedures on the biliary system. In 1951 Gariepy [2] reviewed the literature and found 24 cases of perforation of the common duct; 14 of these were secondary to choledochostomy and 10 were spontaneous. This author added two cases, and in 1951 Hart [3] reported a case, making a total of 13 reported cases of spontaneous rupture of the common duct. The case represented in this paper is, then, the 14th reported in the literature in which perforation of the common duct occurred in the absence of trauma or prior common duct surgery.

REPORT OF A CASE

G. K., a white man, aged 75, was admitted to the medical service of the Albert Einstein Medical Center, Southern Division, on July 8, 1951, complaining of severe precordial pain, beginning the day before admission. At the time of admission he was in shock and had extreme precordial pain. He was cyanotic and had bilateral basal rales. The diagnosis on admission was acute myocardial infarction, and an EKG taken at this time showed evidence of a large myocardial infarction involving the anterior surface of the left ventricle. From admission, on July 8, until Aug. 1, the patient was critically ill, in a state of partial disorientation and excitement, being treated with anticoagulants, and in an oxygen tent. On Aug. 1, he complained of periumbilical pain, and on the following day, of substernal and epigastric pain. The abdomen at this time was distended and silent. In view of the recent myocardial infarction the impression of the medical service was that the abdominal findings were a result of mesenteric embolism. On Aug. 4 his temperature was elevated, his abdomen was very distended and diffusely tender, and he had developed hematuria, which was thought to be due to the anticoagulants. Surgical consultation was requested on Aug. 4, at which time he was running a septic temperature; the abdomen was distended and silent and showed diffuse tenderness and rebound tenderness. Operation was done on Aug. 4, endotracheal ether and oxygen anesthesia being used. There was a large amount of bile-stained fluid throughout the peritoneal cavity; the small intestine, stomach, and duodenum were not remarkable. The gall bladder was shrunken and fibrotic and did not contain any calculi. There was a large perforation in the common duct, which was greatly dilated. The perforation was due to direct pressure from a large, jagged calculus. The gall bladder was removed, the common duct stone removed, and the common duct explored and found to be patent into the duodenum. The perforation was closed, a T-tube placed in the common duct and the abdomen closed with a cigarette drain down to the foramen of Winslow.

The patient had a rather uneventful convalescence, with the exception of auricular fibrillation on Aug. 8, and was discharged from the hospital on Sept. 16, with the T-tube in place but clamped. A cholangiogram done prior to discharge, on Aug. 20, showed normal entrance of

the dye into the duodenum. The cholangiogram was repeated on Aug. 30, with the same findings. Three months after discharge from the hospital the patient was in excellent condition and had no complaints. A cholangiogram at this time showed rapid entrance of the dye into the duodenum. The tube was removed and the opening closed at once with practically no biliary drainage. The patient was last seen in January, 1952, at which time he seemed in excellent health, was active, and had no complaints. The EKG taken at this time showed evidence of a healed anteroseptal myocardial infarction.

COMMENT

Spontaneous perforation of the common bile duct has been attributed to many factors, among them being direct pressure of a calculus on the wall of the duct, thrombosis of the mural vessels of the duct wall with resultant necrosis, increased intraductal pressure due to spasm of the sphincter of Oddi, infection, digestion due to reflux of pancreatic secretions, and diverticulum.

It seems highly improbable that infection would cause the type of localized gangrene of the duct wall that would result in perforation. Hart believed that the local gangrene in the case he reported was due to mural thrombosis. However, in view of the fact that the gall bladder contained numerous calculi, we believe it possible that the perforation seen in his case was due to pressure from a common duct calculus. We believe that the other offered explanations for spontaneous biliary perforation are rather fanciful and that most cases are probably due to direct pressure of an impacted calculus.

SUMMARY

Another case of spontaneous perforation of the common bile duct has been added to the previously reported 13 cases. The cause of perforation in this case was direct pressure from a large jagged calculus. The correct preoperative diagnosis was not made, and we do not have any suggestions which might help in arriving at the preoperative diagnosis. It is our opinion that this condition, rare as it is, will probably go undiagnosed before operation but that the findings of bile or biliary-stained peritoneal fluid will lead to exploration of the biliary region and ultimately to a correct diagnosis. It should be emphasized that the most exacting care should be taken in searching for the point of perforation, which may be missed, as in the case reported by Bailey.* The usual methods of restoration of blood volume to normal, fluid and electrolyte balance studies, and administration of antibiotics should, of course, be used.

* Bailey, cited by Hart.[3]

REFERENCES

1. McWilliams, C. A.: Acute Spontaneous Perforation of the Biliary System into the Free Peritoneal Cavity, Ann. Surg., **55**:235, 1912.

2. Gariepy, L. J.: Nontraumatic Rupture of the Common Bile Duct, New Orleans M. & Surg. J. **105**:55, 1951.

3. Hart, D. E.: Spontaneous Perforation of the Common Bile Duct, Ann. Surg. **133**:280, 1951.

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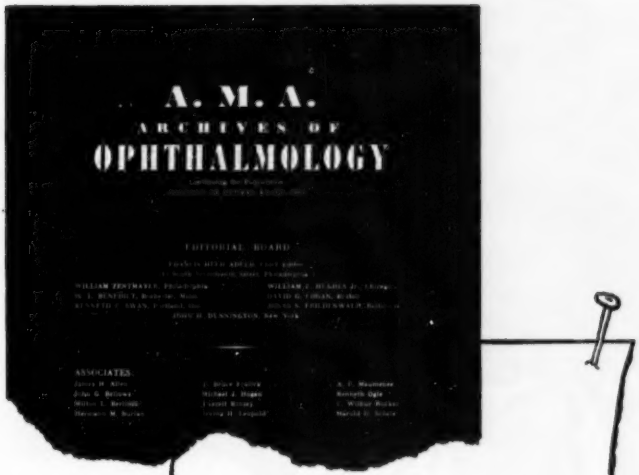

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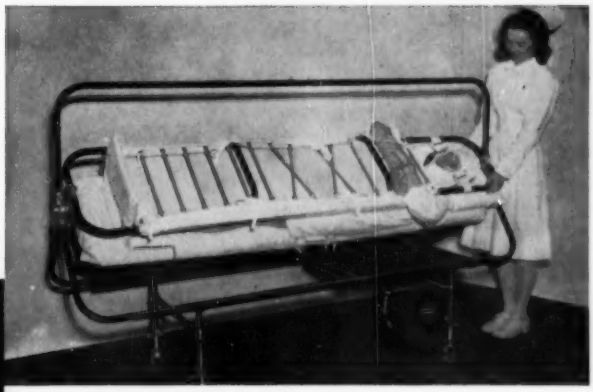

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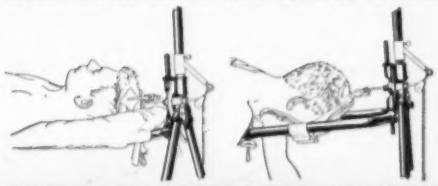

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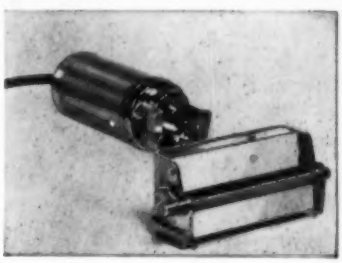

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